

PHILIPS



Digital multimeter

PM 2421

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PHILIPS



Manual

DIGITAL MULTIMETER PM2421

9447 024 21..1



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IMPORTANT

In correspondence concerning this instrument, please quote the type number and serial number as given on the type plate at the rear of the instrument.

I. Introduction

GENERAL

The PHILIPS Digital multimeter PM 2421 is a universal instrument with digital display for the accurate measurement of electrical quantities.

The instrument permits of measuring direct and alternating voltages in a level range of more than $1:10^7$. The frequency range in the case of alternating voltage measurements extends from 10 Hz to 1 MHz.

In conjunction with a measuring probe (optional) it is possible to carry out HF voltage measurements at frequencies up to 700 MHz.

Current and resistance measurements are possible with the PM 2421 in a range greater than $1:10^{10}$.

Range and mode selection is effected with the aid of simple and conveniently arranged pushbuttons. An automatically controlled measuring range selector switches a voltage divider within 3 decades so that the most favourable display value is obtained. If desired, the range selector can also be operated manually.

The measuring data (polarity of the direct voltage, automatically selected range and the digital measuring quantity) are available from the memory in encoded digital form.

With the aid of an additional printed circuit board which can be plugged into the digital section, the digital information is converted into standard levels, thus enabling the connection of a printer or recorder.

Apart from the digital output signal a conventional analogue output signal is also available for continuous recording of the measuring quantity.

The circuit zero is isolated from the housing and from the mains by means of a double screening so that floating measurements are also possible.

The instrument is provided with integrated circuits and silicon semi-conductors.

On account of its high sensitivity, its great accuracy and its rugged construction, the PM 2421 is suitable for research and development as well as for educational purposes, repair service, testing, general industrial applications etc.

II. Technical data

Properties expressed in numerical values with tolerances are guaranteed by the factory.
Numerical values without tolerances serve only for information and represent the properties of an average instrument.

II-1. MEASURING RANGE

II-1.1. Direct voltages

mV-ranges

Full-scale values	19.98 mV, 199.8 mV, 1998 mV
Resolution	10 μ V at the most sensitive range
Input resistance	1 M Ω
Overload protection	max. 500 V d.c.

V-ranges

Full-scale values	19.98 V, 199.8 V, 1000 V
Input resistance	10 M Ω
Overload protection	max. 1000 V d.c.

Accuracy

Relative to full-scale value	$\pm 0.1\%$
Relative to reading	$\pm 0.1\%$

<u>A.C. rejection for frequencies > 50 Hz</u>	min. 80 dB
--	------------

II-1.2. Direct currents

nA-ranges

Full-scale values	19.98 nA, 199.8 nA, 1998 nA
Resolution	10 pA at the most sensitive range
Voltage drop	1 mV/nA

μ A-ranges

Full-scale values	19.98 μ A, 199.8 μ A, 1998 μ A
Voltage drop	1 mV/ μ A

mA-ranges

Full-scale values	19.98 mA, 199.8 mA, 1400 mA
Voltage drop	1 mV/mA

Accuracy

Relative to full-scale value
Relative to reading

$\pm 0.3\%$
 $\pm 0.2\%$

II-1.3. Alternating voltagesmV-ranges

Full-scale values
Resolution
Preliminary indication with short-circuited input
Input impedance
Overload protection

19.98 mV_{rms} 199.8 mV_{rms} 1998 mV_{rms}
10 μ V at the most sensitive range
max. 20 μ V ($\triangle$ 2 digits)
1 M Ω // 40 pF
at frequencies $\leq$ 50 Hz max. 300 V_{rms}
at all other frequencies max. 30 V_{rms}

V-ranges

Full-scale values
Input impedance
Overload protection

19.98 V_{rms} 199.8 V_{rms} 500 V_{rms}
10 M Ω // 25 pF
max. 500 V_{rms} or 750 V_p

Accuracy

20 Hz - 300 kHz: Relative to full-scale
Relative to reading
10 Hz - 20 Hz and 300 kHz - 1 MHz :
Relative to full-scale
At values > 1400 , ≥ 50 kHz
Frequency response

$\pm 0.3\%$
 $\pm 0.2\%$
 $\pm 1\%$
additional error $\pm 0.7\%$ of reading
10 Hz ... 1 MHz

Measuring method

By means of full wave rectifier (for sinewave input voltages, calibrated in rms values).

II-1.4. Alternating currentsnA-ranges

Full-scale values
Resolution

19.98 nA, 199.8 nA, 1998 nA
10 pA at the most sensitive range

Accuracy

10 Hz - 50 Hz
50 Hz - 100 Hz
Voltage drop

$\pm 0.5\%$, relative to full-scale value
 $\pm 0.5\%$, relative to reading
 $\pm 1\%$, relative to full-scale value
 $\pm 0.5\%$, relative to reading
1 mV/nA

 μ A-ranges

Full-scale values
Accuracy 10 Hz ... 10 kHz
100 kHz - 200 kHz
Voltage drop

19.98 μ A, 199.8 μ A, 1998 μ A
0.5%, relative to full-scale value
0.5%, relative to reading
 $\pm 1\%$, relative to full-scale value
 $\pm 1\%$, relative to reading
1 mV/mA

mA-ranges

Full-scale values

Accuracy 10 Hz ... 100 kHz

100 kHz - 200 kHz

Voltage drop

19.98 mA, 199.8 mA, 1400 mA

 $\pm 0.5\%$, relative to full-scale value $\pm 0.5\%$, relative to reading $\pm 1\%$, relative to full-scale value $\pm 1\%$, relative to reading

1 mV/mA

II-1.5. H.F. voltages

To be measured with probe PM 9203

Frequency range

Full-scale values

Minimum measurable H.F. voltage

Accuracy

Input capacitance

Parallel damping resistance

Measurements with probe PM 9203 and T-connector

Frequency range

Accuracy

300 kHz ... 700 MHz

19.98 mV_{rms} 199.8 mV_{rms} 1998 mV_{rms}

2 mV

See chapter XIV

 ≤ 2 pFDependent on voltage and frequency,
between 10 k Ω and 200 k Ω

PM 9253

300 kHz ... 1200 MHz

700 kHz ... 1200 MHz $< +5$ dB -0 dBII-1.6. Resistances Ω -range

Full-scale values

Resolution

Accuracy

Measuring current

Measuring voltage

19.98 Ω , 199.8 Ω , 1998 Ω 0.01 Ω in range 19.98 Ω $\pm 0.2\%$, relative to full-scale value $\pm 0.2\%$, relative to reading

1 mA

2 V max.

k Ω -range

Full-scale values

Accuracy

Measuring current

Measuring voltage

19.98 k Ω , 199.8 k Ω , 1998 k Ω $\pm 0.2\%$, relative to full-scale value $\pm 0.2\%$, relative to reading5 μ A

7 V max.

M Ω -range

Full-scale values

Accuracy

Measuring current

Measuring voltage

19.98 M Ω , 199.8 M Ω , 1998 M Ω $\pm 0.3\%$, relative to full-scale value } up to
 $\pm 0.2\%$, relative to reading } 100 M Ω $\pm 2\%$, above 100 M Ω

5 nA

7 V max.

II-2. GENERAL DATA

II-2.1. Range selection

Range group with push-buttons, manually.

Three ranges within each group, chosen by means of automatic range selector; also manually adjustable.

II-2.2. Temperature range

For the stated accuracy

$23^{\circ}\text{C} \pm 5^{\circ}\text{C}$

Temperature coefficient (except for H.F. measurements) between $-10^{\circ}\text{C} \dots 45^{\circ}\text{C}$

$\leq 200 \text{ ppm}/^{\circ}\text{C}$

Typical value

$\leq 100 \text{ ppm}/^{\circ}\text{C}$

II-2.3. Power supply

Mains voltage

115 V and 230 V $\pm 15\%$

Mains frequency

50 ... 60 Hz

Power consumption

22 VA

Capacitance between mains and circuit zero

$< 50 \text{ pF}$

Capacitance between "LO" and chassis

1.5 nF

Permissible direct voltage between chassis and circuit zero

max. 500 V

II-2.4. Common mode rejection

120 dB

II-2.5. Timing

Integration time

100 ms

Integration time without range selection

for d.c. approx. 750 ms

for a.c. approx. 2 s

Range selection

approx. 100 ms

II-2.6. Analogue output

Voltage per digit

3.5 mV

Max. output voltage

7 V

Source resistance

$5 \text{ k}\Omega \pm 0.25\%$

II-2.7. Digital output

With additional printed circuit board PM 9221.

II-3. MECHANICAL DATA

Dimensions

Width 305 mm

Height 145 mm

Depth 270 mm

Weight

7 kg.

III. Accessories

- Mains lead
- Fuse indication plate for mains voltage
- Measuring cable, complete with one measuring probe holder, two measuring clips and measuring probe tip. (Fig. 1A, page 50)
- Measuring terminal (Fig. 1B, page 50)
- 2.5 mm Allen key
- Manual

OPTIONALLY AVAILABLE

- EHT probe PM 9246 (Fig. 2, page 50)

The HT probe PM 9246 is suitable for measuring direct voltages up to 30 kV.

The PM 9246 may be used for measuring instruments with an input impedance of 100 M Ω , 10 M Ω or 1.2 M Ω (selectable).

TECHNICAL DATA

Maximum voltage	30 kV
Attenuation	1000 x
Input impedance	600 M Ω $\pm$ 5%
Accuracy	$\pm$ 3% for instruments input impedance of 10 M Ω and 100 M Ω $\pm$ 5% for instruments input impedance of 1.2 M Ω

Note: Pay attention to safe earth connections

- HF probe PM 9203 (see chapter XIV)
- HF-T-piece PM 9253 (see chapter XIV)
- Digital output unit PM 9221 (see chapter XV)
- Plug-in cabinet PM 9706 (Fig. 3, page 50)

PM 9706 is an universal 3E-cabinet, with a width of 6 modules. It is provided with side panels including handles, feet, tilting bracket, top and bottom plate, guiding strips and a grey, plastic cable cover, in which two brackets are located for 19" rack mounting.

- Blank panel PM 9722

PM 9722 is a blank panel for a 3E-cabinet, having a width of 2 modules, to fill the blank space when the PM 2421 is mounted in cabinet PM 9706.

- Blank panel PM 9721

PM 9721 is a blank for a 3E-cabinet, having a width of 1 module.
Two panels PM 9721 can be used instead of one PM 9722.

IV. Principle of operation

IV-1. BLOCK DIAGRAM (Fig. 4, page 54)

Both the modes and the ranges are selected by means of push-buttons.

Dependent on this selection, the functional units are arranged so that an optimum measuring result is obtained. In this respect the following functions can be distinguished:

a. Arrangement of the functional units

The AC or DC amplifier, the direct current generator and the 300 kHz oscillator are connected to the appropriate input dependent on the mode of operation and are then connected to the analogue to digital converter.

Various combinations are then possible (see under point IV-2)

Moreover, in the case of a.c. and H.F. measurements, a low-ohmic voltage divider is included between the two a.c. amplifiers and in the case of d.c. and resistance measurements this divider is connected to the output of the d.c. amplifier.

b. Pre-selection of the measuring ranges

In the case of voltage or current measurements the input signals are matched to the inputs in accordance with the selected range. This pre-selection is effected in 10^3 steps, such as e.g. for nA, μ A and mA.

c. Auxiliary functions

The push-button switch performs various auxiliary functions such as short-circuiting the current terminals in the case of voltage and resistance measurements.

In the case of d.c. measurements it provides the polarity indication, and in the case of a.c. and h.f. measurements the sine symbol and it eliminates these signs in the case of resistance measurements.

IV-1.1. D.C. amplifier

This amplifier serves for measuring direct voltages, direct currents and resistance values.

In the case of H.F. measurements it operates as a very sensitive control amplifier.

This amplifier is chopper - stabilised and has a d.c. gain of more than 5×10^7 .

IV-1.2. A.C. amplifier and a.c. - to - d.c. converter

The a.c. amplifier and the a.c. - to - d.c. converter are operative in the case of alternating current, alternating voltage and H.F. measurements.

The first a.c. amplifier section is an impedance matching stage supplying the low-ohmic voltage divider.

The second voltage amplifier is followed by the a.c. to d.c. converter, which supplies an output voltage which is symmetrical with respect to earth. This direct voltage which is exactly proportional to the input a.c. signal, is converted in a d.c. difference amplifier into an output voltage, which is asymmetrical with respect to the circuit zero.

IV-1.3. Current generator

The current generator supplies a constant direct current of 1 mA, which is employed for resistance measurements. To avoid long measuring times, the output voltage is limited.

IV-1.4. H.F. section

The H.F. section comprises a L-C oscillator operating at 300 kHz.

The 300 kHz output voltage is controlled by a regulator until it is equal to the H.F. voltage to be measured.

The principle of H.F. measurements is further described under point IV-2.3 of this chapter.

IV-1.5. Voltage divider

Within the pre-selected coarse range voltage division is effected in three decades. The low-ohmic voltage divider consisting of precision resistors, is automatically controlled by a reed relay.

The switching pulses for the relay are obtained from the digital section.

Changing over to the relevant measuring range is effected automatically but manual operation is also possible.

IV-1.6. Digital section

The analogue to digital converter converts the analogue input signal into a digital signal. The digital information is first stored and then transferred to the display section. As long as the measuring value remains the same, the same value will be displayed. When the measuring value changes, the new value is displayed and is retained until the value changes again. When the measuring value is equal to or greater than 1998, the pilot lamp "OVERLOAD" indicates that the end-of-range value is exceeded.

IV-1.7. Power supply

The stabilised supply circuits provide the voltages required for the various sections. The + 15 V and -15 V direct voltages serve also as reference for the analogue to digital conversion. All supply circuits are protected against short-circuiting and brief overloads.

IV-2. FUNCTIONAL DIAGRAM

Fig. 5, page 54 shows the functional diagram. Dependent on the measuring mode the individual units are combined by means of the push-button switch.

A survey of the circuit arrangements for the various modes of operation is given below.

IV-2.1. D.C. measurements (Fig. 6, page 58)

The 1:1000 input attenuator divides the voltage in the measuring range "V" so that the output signal corresponds to that in the "mV" range and can be processed by the instrument. In the case of current measurements the voltage across the shunt is measured.

The direct voltage measurement is based on the gain of a chopper-stabilised d.c. amplifier, which depends on the degree of feedback. The resulting analogue output signal is converted into a digital signal by means of an analogue to digital converter. A.C. interference superimposed on the measuring signal is suppressed by a low-pass filter. The signal on the input of the d.c. amplifier is inverted by this amplifier. The voltage amplification of the circuit depends practically only on the voltage divider and the resistors in the feedback circuit, the internal amplification being very high.

At the "mV" ranges when the input signal is applied directly, the voltage gain is 3.5-times (upper relay contact closed), in the case of a 10:1 division (centre contact closed) it is 35 times, and in the case of 100:1 division (lower contact closed) it is 350 times.

An input voltage of 10 mV causes an analogue output voltage of 3.5 V at the highest sensitivity (gain factor of 350). This voltage corresponds to an indication of 10.00 in the digital section (button "mV" depressed).

IV-2.2.A.C. measurements (Fig. 7, page 58)

The a.c. signal to be measured is applied to the input of the impedance matching stage in the mV ranges. In the V ranges and in the current ranges the same voltage divider elements and shunts are employed as in the corresponding d.c. ranges. This means that in fact all a.c. measurements are reduced to voltage measurements at the mV ranges.

The d.c. components are blocked by a capacitor at the input of the impedance matching stage. Alternating voltages are matched to a low output impedance in the impedance matching stage which has unity gain.

The voltage divider connected to the impedance stage is also employed for d.c. and resistance measurements, but in the case of a.c. measurements the sensitivity steps are reversed.

As a result, the output voltage on the analogue output is 3.5 V d.c. when the upper contact is closed, if a sinusoidal input voltage of 10 mV r.m.s. is applied.

The voltage divider of the automatic range selector is followed by an a.c. amplifier with a high input impedance. The a.c. to d.c. converter comprises a wideband amplifier with a high no-load gain and a full-wave rectifier network included in the negative feedback circuit. This results in average value rectification of high linearity. The output voltage of the a.c. to d.c. converter is symmetrical with respect to the circuit zero and will contain a.c. components. Therefore, the signal is filtered and applied to an impedance matching stage. The following difference amplifier makes the signal asymmetrical with respect to the circuit zero, after which the value is determined by the digital section and the analogue output circuit.

IV-2.3.H.F. voltage measurements (Fig. 8, page 58)

The H.F. voltage measurements are based on the compensation principle.

For this purpose the amplitude of the voltage required for compensation is controlled so that the input and the compensation voltage have the same value. The measuring probe contains two pairs of diodes, one pair in the H.F. input circuit and the other pair in the compensation circuit. The direct current supplied by the diodes controls the d.c. amplifier which has a very high gain if there is no negative feedback. The output voltage of the d.c. amplifier controls the oscillator and the control amplifier of the latter so that the oscillator voltage which is used as compensation voltage becomes equal to the H.F. input voltage. The polarity of the rectified H.F. voltage is opposite to that of the rectified compensation voltage.

When the two voltages have the same value, the resulting d.c. output voltage will be zero. On the input of the a.c. to d.c. converter a 300 kHz signal arises, whose amplitude has the same value as that of the H.F. signal to be measured. This 300 kHz compensation voltage is measured by the digital section via the a.c. - to - d.c. converter in the same way as with a.c. voltages in the mV ranges.

Errors arising on account of the spread in tolerances of the rectifier diodes in the input circuit are practically eliminated by employing diodes with the same properties in the compensation circuit.

IV-2.4. Resistance measurements

Resistance measurements at the Ω -ranges are effected by measuring the voltage drop across an unknown resistance. (Fig. 9, page 59) A current generator supplies a constant current of 1 mA flowing through the resistance to be measured. The voltage drop across the resistor is proportional to the resistance value and is measured by the direct voltage measuring circuit after which it is displayed.

At the k Ω and M Ω ranges the current from the current generator flows through a 6.98 Ω resistor (Fig. 10, page 59)

As a result a 6.98 mV voltage source is obtained and the resistance to be measured which is included in the feedback circuit then changes the gain of the d.c. amplifier.

The voltage on the analogue output depends on the position of the voltage divider and is exactly proportional to the value of R_x . The drive circuit of the d.c. amplifier comprises resistor R1. The value of this resistor defines the $k\Omega$ and $M\Omega$ ranges, because the current through R_x in the feedback circuit assumes the value determined by R1. The voltage on the output of the amplifier is measured by the analogue to digital converter and displayed.

IV-2.5. Display section (Fig. 12, page 64)

Conversion of the analogue signals into digital form is based on the dual slope principle in PM 2421.

The analogue input signal is applied to the integrator via series resistors and switching transistors. The integrator supplies an output pulse whose width is proportional to the measuring value.

The working principle of the integrator is described in more detail in the following chapter.

Fig. 11, page 59 shows a graphical representation of the voltage as a function of time during the charging and discharging cycle.

During the integration process two main conditions should be distinguished which will be called upward integration (first step) and downward integration (second step).

During the first step (start) a current is applied to the integrator, which is proportional to the input voltage (S1 open, S2 and S3 closed).

The output voltage of the integrator increases linearly as a function of time; its direction depends on the polarity, and its steepness on the value of the input voltage. The integration time is determined by the duration of 1000 clock pulses. During this interval upward integration is effected and capacitor C402 is charged.

At the end of the first step the polarity of the integration voltage is determined and indicated.

At this moment the counter supplies the transfer pulse, which initiates the downward integration and at the same time sets the counter to zero.

During the second step the integrator is discharged to zero by a constant current (S1 closed, S2 or S3 open, dependent on the polarity determined during the first step). The discharge rate is determined by the discharge current and, consequently, by the reference voltage, so that it will be constant. The time is measured by counting the number of clock pulses; it is directly proportional to the unknown input voltage applied during the first step.

As the same integration elements and clock generator are employed for both steps, temperature variations, long-term drift and absolute values will not affect the measuring accuracy.

The measuring accuracy in the first place depends on the accuracy of the reference voltage.

Even without filters, this type of circuit is not sensitive to superimposed alternating voltages, because these are also integrated, i.e. the average value is determined.

As soon as the voltage on integrating capacitor C402 passes through zero during the discharge process, the gate is closed and the contents of the counter is transferred to the memory and displayed. The counter also controls the automatic range selector, which has three different ranges.

At a measuring value of more than 1998 units the next range is selected.

When in the upper range the measuring value is again equal or more than 1998, pilot lamp "OVERLOAD" lights up and indicates that the measuring voltage has exceeded the permissible value and that the displayed result is no longer reliable. If an indication of 180 units is not obtained, the automatic range selector changes over to a more sensitive range. The selected range can be derived from the position of the decimal point. At each step of the automatic range selector the starting moment for the next measurement is delayed by 100 msec. by the delay flip-flop.

The pre-amplifiers of the a.c. , d.c. and H.F. ranges are then adapted to the new measuring value during this delay. "

V. Installation

DIRECTIONS FOR USE

V-1. Adjustment to the local mains voltage

Before the instrument is put into operation, check that the instrument is adapted to the local mains voltage. The voltage to which the instrument is set in the factory, can be read on an indication plate at the rear of the instrument (220 V or 115 V). At these voltage values deviations of $\pm 15\%$ are permissible; fuse VL1 should have the following rating:

Nominal value	Voltage range	Fuse VL1
230 V	200 ... 264 V	160 mA delayed action
115 V	100 ... 132 V	250 mA delayed action

Adjustment to a different voltage range is effected by resoldering the two jumpers on the mains transformer. For this purpose the chassis should be pulled out of the cabinet (caution, the instrument should not be connected to the mains) with the two locking devices (see chapter VIII-1). For the two voltage ranges the jumper should be connected as indicated in Fig. 13, page 65. When the instrument has been adapted to a new voltage value, the indication plate at the rear of the instrument should be changed accordingly.

Connection to the mains:

The instrument should be connected to a socket with rim earthing contacts by means of the three-core mains lead supplied with the instrument.

V-2. Earthing

When the instrument is connected to the mains via the three-core mains lead the housing is connected to safety earth.

If for safety reasons separate earthing of the instrument housing is desired (e.g. when measuring high voltages) the instrument may be earthed by means of a separate lead which should be connected to the earthing screw ($\perp$) at the rear (Fig. 14, page 65).

The instrument is equipped with a special mains transformer whose primary winding is enclosed by a screening on both sides. These screenings are connected to safety earth so that capacitive earthing currents from the primary winding are drained to safety earth via the screening.

The maximum permissible voltage between measuring input "LO" and the cabinet is 500 V d.c. Furthermore, earthing should be effected in accordance with local safety regulations.

V-3. Combining the instrument with other modules

The chassis of the PM2421 may be accommodated in a 6-module cabinet (PM 9706) instead of the 4-module cabinet. The additional space in this cabinet can then be used for other units of the 3E modular system, being employed in conjunction with a digital voltmeter or independently. This 6-module cabinet is suitable for mounting in 19" racks. When the additional space is not used, it can be closed off by means of a blank plug-in chassis.

For converting the instrument into the rack mounting version, proceed as follows:

- Remove the grey, plastic cable cover from the PM 9706 cabinet and take out the brackets
- Remove the four screws at the two sides
- Slightly lift the side plates at the front and remove the plastic plates which are now accessible. The brackets can now be placed in the free space.
- Refit the side plates and secure them with the four screws
- Remove the four feet
- Mount the desired number of guide rails to the upper and lower crossbars. The appropriate holes in the crossbars are threaded.
- Slide the PM 2421 out of the 4-module cabinet and slide it into the 6-module cabinet
- Fill the free space with one unit PM 9722 or two units PM 9721
- Lock the PM 2421 and PM 9722.

VI. Operation

VI-1. Switching on

After connection to the mains and earthing, the instrument is ready for operation.

By means of mains switch "POWER ON" the instrument is switched on; the display tubes light up.

VI-2. Mode selection

Mode

The mode is selected by push-buttons, by means of which simultaneously the range group is selected in steps of 10^3 i.e. 1:1, 1:1000 or 1:1000000.

Within these pre-selected ranges, dependent on the measuring value, the instrument is automatically switched over to ranges with a ratio 1:1, 1:10 or 1:100, with corresponding display of the decimal point.

The modes d.c. and R (direct current, direct voltage measurements and resistance measurements) have a common push-button switch.

Connection

For connection of the test circuit, separate sockets are available for voltage, current and resistance. Interaction between these circuits is impossible, because the push-button switches are interlocked. The left-hand "I" and "V" sockets are connected to the circuit zero and may be employed as LO (LOW).

For measuring H.F. voltages (> 1 MHz) the special H.F. probe (with T-connector for coaxial lines) should be employed. This probe must be connected to 5-pole socket "HF" on the front panel.

VI-3. Measuring value display and measuring range selection

The measuring result is displayed by means of cold-cathode tubes, the decimal point being indicated by a spot in these tubes.

Changing over of the measuring ranges is effected automatically but may also be done manually.

Automatic operation

In the case of automatic operation the low-ohmic voltage divider receives switching commands which depend on the measuring value.

If the measuring value at the least sensitive ranges is 180 or less, a more sensitive range step is selected and if the measuring value is 1998 or higher a less sensitive position is selected, if possible.

This automatic switching process continues until either the indication lies between 180 and 1998 or until one of the two extreme range positions is attained. When the indication in the least sensitive range is 1998 or higher, pilot lamp "OVERLOAD" also lights up, because the guaranteed measuring limit of the relevant pre-selection range is then reached.

At the most sensitive range the indication is also stable below 180. In the range between 180 and 1998 the display is also retained if a higher accuracy would be possible for values between 1800 and 1998. This situation arises when the least sensitive position is switched on due to overloading or fluctuation of the measuring quantity.

However, it is simple to force the automatic range selector to start the measurement at the most sensitive range so that an indication between 1800 and 1998 is obtained at corresponding measuring quantities.

In the case of voltage and current measurements it suffices to briefly switch on the higher coarse range by means of the corresponding push-button, or to interrupt the measuring circuit briefly. In the case of resistance measurements a brief short-circuiting of the R-sockets will cause the instrument to change over to the next, more sensitive range.

Manual operation

Manual range selection is more advantageous in the case of series measurements in a single range. For part of the measuring values the measuring speed is then increased, as the switching times are eliminated.

The switch for manual selection is located at the rear of the instrument and can be operated by means of a screwdriver.

The switch has 4 steps: 1000, 100, 10 and AUTO. In position "AUTO" range selection is effected automatically, in the other positions the relevant ranges are switched on.

VI-4. Polarity indication

In the case of d.c. measurements the polarity is indicated automatically on a cold-cathode tube with the + or - symbol. This indication refers to socket HI (High). In the case of resistance measurements the tube extinguishes and in the case of a.c. and h.f. measurements symbol "~" lights up.

VI-5. Direct voltage measurements

For the d.c. mode push-button "DC/R" should be depressed. Up to input voltages of 1.998 V the "mV" button should be depressed and at higher voltages the "V" button. Before the measuring voltage is applied, it should be checked that the most sensitive measuring range is switched on; the position of the decimal point should be 00.00.

Control "0" serves for zero adjustment; it should be adjusted so that in the case of an open-circuited measuring circuit all digits are zero. After this the zero control should be set to a position at which the polarity reverses, i.e. at the +/- transition.

When the voltage to be measured is applied to sockets "V" the measuring value and the polarity of the voltage are displayed.

When measuring very low voltages (below a few mV) it may be desirable to measure the voltage without the thermal voltage arising in the measuring lead. In this case zero adjustment should be effected after short-circuiting the measuring leads near the source. Thermal voltages in the measuring circuit can easily be compensated for with the zero control.

After the adjustment and after removing the short-circuit the voltage source to be measured may be connected.

H.T. measurements

For measuring voltages between 1 kV and 30 kV H.T. probe PM 9246 is available. This probe should be connected to sockets "V", whereby the measuring pole should be connected to "HI" and the "≡" pole of the plug to "LO".

Select the 10 MΩ range on the probe.

The value indicated by the PM 2421 in the V-range should then be multiplied by factor 100.

CAUTION ! ! !

Always connect the earthing wire of the probe to chassis or the zero pole of the h.t. source, before the high voltage is touched with the probe.

VI-6. Alternating voltage measurements

The AC mode is selected with push-button "AC". With buttons "mV" and "V" the coarse voltage ranges can be selected; up to 1.998 V button "mV" should be depressed and at higher voltages up to max. 500 V, button "V". When connecting the voltage source to be measured, it should be observed that the potential which is closest to earth potential is connected to socket "LO". To avoid measuring errors the measuring lead should be connected so that no loop formation occurs. Capacitively induced currents from the mains will cause voltage drops in the measuring leads, which may affect the measurement.

The applied alternating voltage may be superimposed onto a direct voltage up to 400 V.

VI-7. Current measurement

In the case of voltage and resistance measurements sockets "I" are short-circuited and are connected to the circuit zero. For direct current measurements the "DC/R" button should be depressed and for alternating current the A.C. button. Dependent on the current to be measured, one of the three buttons "nA", "µA" or "mA" should be depressed. If the order of magnitude of the current to be measured is not known, it is recommended to start at the highest measuring range, i.e. mA. Otherwise the shunt resistors may be damaged.

The current circuit, especially in the case of AC measurements, should be connected so that the potential which is closest to earth potential is connected to socket "LO". In the case of alternating current measurements check that no earthing loops arise!

The voltage drop is 1 mV per nA, per µA or per mA, dependent on the selected range. If in the case of current measurements the voltage drop is of importance (at low internal resistance), the measurement may be effected in two different ranges. The influence of the different ranges can then be derived from the measuring result.

By means of corresponding separate shunt resistors it is possible to keep the voltage drop on the "I" sockets below 19.98 mV for all current values.

In the current circuit (via terminals I, BU4 and BU5) a 1.6-A-fuse has been incorporated to protect the shunt resistors R6 and R10 against overloads.

The fuse is fitted in a fuse holder, mounted at the bottom-side near the terminals I, HI and LO.

VI-8. Resistance measurements

For measuring resistance values button "DC/R" should be depressed.

Sockets R serve for connecting the test object. By means of buttons Ω , k Ω , or M Ω the coarse range can be selected. The measurement is effected with the aid of direct current.

As a result, it is also possible to measure the resistance of coils and transformer windings.

WARNING ! ! !

Because the measuring circuit for resistance measurements is not protected against external voltages this should be carefully handled. Therefore it may be possible to damage several components, if an external voltage, larger than 5 V_{rms}, is connected to terminal BU2 and BU3. Be carefull with measuring resistances carrying voltages.

Zero adjustment should be effected as follows:

Ω ranges:

At the Ω ranges sockets R should be short-circuited. The indication can then be set to 0000 with the zero control. When the resistance value of the measuring leads should not be included in the measuring result, the short-circuit should be made at the test object. If the indication is then set to 0000 with the DC zero control, the resistance of the measuring leads is compensated for within a small range.

K Ω and M Ω ranges

In these ranges the measuring arrangement is different (also see point IV-2.4). The zero adjustment then does not depend in the first place on the resistance value but on the gain. Therefore, the "V" button should be depressed for zero adjustment.

The indication should then be set to 0000 with the zero control.

After this release the "V" button again and depress the k Ω or M Ω button.

In this case it is not necessary to short-circuit the R-sockets. At very low resistance values it should be taken into account that possible thermal voltages may affect the measuring result. In such critical cases it is advisable to effect the zero adjustment procedure as described under " Ω ranges". The short-circuit should then be made direct at the test object and not at the sockets.

In the Ω ranges a current of 1 mA flows through the unknown resistance.

On account of this it is also possible to compare semi-conductors as regards diode voltage and temperature drift at a forward current of 1 mA.

At higher resistance values (above 100 M Ω) the measuring time is relatively long on account of the low test current. Hum may then affect the measuring result. To prevent this it is recommended to screen the high-ohmic resistor, the screening being connected to the circuit zero, e.g. to socket LO of the I-input.

VI-9. HF voltage measurements

VI-9.1. General

For H.F. measurements at frequencies > 1 MHz probe PM 9203 as well as a capacitive divider 100:1 may be used and for measurements to co-axial lines T-connector PM 9253 is available.

By means of the latter H.F. voltages with frequencies up to 1200 MHz can be measured.

The HF range of the PM 2421 is a very sensitive HF detector due to the applied regulating system. This does not only apply for the signal under test but in the same way for all kinds of interference voltages. Signals in the order of magnitude of some μ V are detected and indicated by the PM 2421. High interference-fields, appearing near TV- and radio transmitters, may give rise to these interference voltages. Other sources of interference are e.g. rotary electric machines, motors controlled by thyristors etc.

The calibration feasibility of the PM 2421 for HF measurements is designed for very small voltages, to improve the diode-characteristics of the four diodes in the probe.

Calibration with knob "HF ADJ." may prove necessary if voltages smaller than 10 mV have to be measured accurately. The accuracy for voltages larger than 10 mV are practically not influenced by the calibration.

To use the sensitivity of the PM 2421 to its full capacity it is necessary to carry out sensitive measurements in a Faraday-cage. In such a cage it is also possible to calibrate the instrument without troubles.

The interference signals may be injected in the following ways:

- By the local mains supply via the mains transformer.
- As a voltage between socket "LO" and the cabinet (the cabinet is not an ideal conductor of H.F. current).
- Via real improvement of the interference set up, which may be influenced by a HF field.

A real improvement of the interference voltage sensitivity is hardly possible. Therefore we can give the following directions:

- If the sensitivity of the instrument has to be used to its full extent, the measurements have to be carried out in an interference free room (Faraday-cage). Calibration and measurements may be effected here without troubles.
- Calibration "HF ADJ." is only necessary for measurements ≤ 10 mV if maximum accuracy is required.
- The "HF ADJ." adjustment has no noticeable influence on the accuracy for measurements larger than 10 mV. The instrument meets the specified accuracy at higher voltages without calibration.

The measuring probe should be connected to the 5-pole socket at the front of the instrument. The mode is selected with push-button H.F. , the measuring range with button "mV". At voltages below 10 mV and in the case of large temperature variations calibration is necessary. For this control "ADJ" at the front and socket "300 kHz OUT" at the rear of the instrument should be used. The reference voltage available on socket "300 kHz OUT" serves for calibration.

VI-9.2. Calibration

- Switch on the instrument.
- Depress buttons "AC" and "mV".
- Connect socket "300 kHz OUT" at the rear to socket "V" - "HI" by means of a connection wire.
- Connect the HF probe to socket "300 kHz OUT" and connect the earthing wire of the probe to socket LO.
- Read the measuring result (observe a waiting time of approx. 20 sec).
- Depress button H.F.
- Accurately adjust the indication to the previous reading with potentiometer "ADJ".
- Fix the arrow of control "ADJ" so that the arrow points upwards in the calibrated condition.
- Disconnect the probe from socket V HI and remove the connection from socket "300 kHz OUT".

Usually this procedure will have to be carried out only once.

However, for H.F. measurements it should always be observed that the arrow of the control points exactly upwards, as the potentiometer is then in the calibrated position (provided that it has been correctly fitted during calibration).

Calibrated instruments should only be used in conjunction with the same probe as used for calibration. However, it is possible to calibrate several instruments with the same probe.

NOTE: If the PM 9203 (HF measuring probe) is connected to the PM 2421 and short-circuited, and indication will be produced (< 2 mV) due to the fact that, with very small input voltages, there is insufficient signal voltage to enable the regulating system to function properly.

VI-9.3. Measurement

Voltage measurements above 10 mV and at frequencies up to 300 MHz require no special measures. At low input voltage (below 5 mV) the indication is obtained rather slowly. Possible interference caused by H.F. fields may be eliminated by short-circuiting sockets V (HI and LO) and simultaneously connecting the R-sockets to LO of socket V.

For all HF measurements it should be observed that the housing of the probe is connected to a proper measuring earth by means of the accessory earthing lead. The earthing connection should be kept as short as possible; if necessary, screen the circuit (to prevent H.F. interference caused by radio transmitters).

For measuring voltages at high frequencies it is recommended to use the T-connector.

This T-connector can be included in the test circuit by means of the co-axial cable with BNC connectors. The HF probe is connected to the H.F. leads by screwing it into the T-connector. For measurements at the voltage range from 1.998 V ... 199.8 V a capacitive voltage divider with a division ratio of 100:1 is provided.

As this divider precedes the measuring diodes, the position of the decimal point will no longer be correct. Therefore, the indication in the mV range should be multiplied by 100.

VI-10. Analogue output

In the analogue circuit all measuring voltages are converted into direct voltages of the same order of magnitude. The value of this direct voltage, within a certain range, is directly proportional to the input quantity and is 3.5 mV per digit; it follows that for the full-scale value of 2000 the output voltage will be 7 V. To prevent the indication from being affected in the case of short-circuiting of the analogue output, a 5.6 k Ω resistor has been connected in series with the analogue voltage source.

The analogue output is located at the rear of the instrument and the relevant sockets are marked "ANALOG OUT". Thus it is possible to use the PM 2421 as a sensitive d.c. amplifier and to record the measuring result with the aid of recording equipment.

I. Einleitung

ALLGEMEINES

Das PHILIPS "digital multimeter" PM 2421 ist ein Universalgerät für die genaue Messung von elektrischen Grössen, mit digitaler Messwertanzeige.

Gleich- und Wechselspannungen können in einem Pegelbereich von über $1:10^7$ gemessen werden. Der Frequenzbereich bei Wechselspannungsmessung erstreckt sich von 10 Hz bis 1 MHz. Mit einem zusätzlichen Tastkopf sind HF-Spannungsmessungen bis zu Frequenzen von 700 MHz möglich.

Strom- und Widerstandswerte lassen sich mit dem PM 2421 in einem Bereich von über $1:10^{10}$ genau messen.

Die Wahl der Messart und der Grössenordnung der Bereiche geschieht mit einfach bedienbaren und übersichtlich angeordneten Drucktasten.

Ein automatisch gesteuerter Messbereichumschalter schaltet einen Spannungsteiler innerhalb von drei Dekaden auf einen günstigen Anzeigewert. Bei Bedarf ist dieser Bereichsschalter auch manuell bedienbar.

Die Daten des schnell und stabil angezeigten Messwertes (Polarität der Gleichspannung, der automatisch gewählte Bereich und die in Ziffern ausgedrückte Grösse) sind in codierter, digitaler Form aus dem Speicher erhältlich. Mit einer an den Digitalteil ansteckbaren Zusatzkarte wird die digitale Information auf normierte Pegelwerte übersetzt, was eine Auswertung der Messdaten mittels Drucker oder Registriergerät ermöglicht.

Neben der digitalen Anzeige steht auch ein normierter, analoger Ausgang für die kontinuierliche Registrierung der Messgrösse zur Verfügung.

Der Schaltungsnullpunkt ist vom Gehäuse isoliert und vom Netz durch doppelte Abschirmung getrennt, so dass auch erdfrei gemessen werden kann.

Das Gerät ist mit integrierten Schaltungen und Siliziumhalbleitern bestückt. Durch die hohe Empfindlichkeit, grosse Genauigkeit und mechanische Robustheit eignet sich das PM 2421 für Forschung, Entwicklung, sowie für Lehreinrichtungen, Reparaturservice, Kontrolle, allgemeine industrielle Anwendungen u.s.w.

II. Technische daten

Eigenschaften, die in Zahlenwerten mit Toleranz angegeben sind, werden von der Fabrik garantiert. Zahlenwerte ohne Toleranzangabe dienen zur Orientierung und entsprechen den Eigenschaften eines Durchschnittsgerätes.

II-1. MESSBEREICHE

II-1.1. Gleichspannung

mV-Bereiche

Bereichsendwerte	19,98 mV; 199,8 mV; 1998 mV
Auflösung	10 μ V im empfindlichsten Bereich
Eingangswiderstand	1 M Ω
Zulässige Spannung am Eingang	max. 500 V DC

V-Bereiche

Bereichsendwerte	19,98 V; 199,8 V; 1000 V
Eingangswiderstand	10 M Ω
Zulässige Spannung am Eingang	max. 1000 V DC

Messunsicherheit

vom Bereichsendwert	+ 0,1%
von der Ablesung	$\pm$ 0,1%

<u>Wechselspannungsunterdrückung für > 50 Hz</u>	min. 80 dB
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II-1.2. Gleichstrom

nA-Bereiche

Bereichsendwerte	19,98 nA; 199,8 nA; 1998 nA
Auflösung	10 pA im empfindlichsten Bereich
Spannungsabfall	1 mV/nA

μ A-Bereiche

Bereichsendwerte	19,98 μ A; 199,8 μ A; 1998 μ A
Spannungsabfall	1 mV/ μ A

mA-Bereiche

Bereichsendwerte	19,98 mA; 199,8 mA; 1400 mA
Spannungsabfall	1 mV/mA

Messunsicherheit

vom Bereichsendwert
von der Ablesung

$\pm 0,3\%$
 $\pm 0,2\%$

II-1.3. WechselspannungmV-Bereiche

Bereichsendwerte
Auflösung
Vorausschlag bei kurzgeschlossenem Eingang
Eingangsimpedanz
Zulässige Spannung am Eingang

19,98 mV_{eff}; 199,8 mV_{eff} ; 1998 mV_{eff}
10 μ V im empfindlichsten Bereich
max. 20 μ V ($\triangle$ 2 Ziffern)
1 M Ω // 40 pF
max. 300 V_{eff} bei Frequenzen von $\leq$ 50 Hz
max. 30 V_{eff} für alle übrigen Frequenzen

V-Bereiche

Bereichsendwerte
Eingangsimpedanz
Zulässige Spannung am Eingang

19,98 V_{eff} ; 199,8 V_{eff} ; 500 V_{eff}
10 M Ω // 25 pF
max. 500 V_{eff} 750 V_s

Messunsicherheit

20 Hz - 300 kHz : vom Bereichsendwert
von der Ablesung
10 Hz - 20 Hz und 300 kHz - 1 MHz :
vom Bereichsendwert
Bei Messwerte >1400, $\geq$ 50 kHz

$\pm 0,3\%$
 $\pm 0,2\%$
 $\pm 1\%$
zusätzlicher Messfehler $\pm 0,7\%$ von der
Ablesung

Frequenzbereich

10 Hz ... 1 MHz

Messart

Doppelweggleichrichter mit Mittelwertbildung, für sinusförmige Eingangsspannungen in Effektivwerten geeicht.

II-1.4. WechselstromnA-Bereiche

Bereichsendwerte
Auflösung

19,98 nA; 199,8 nA; 1998 nA
10 pA im empfindlichsten Bereich

Messunsicherheit

10 Hz ... 50 Hz
50 Hz ... 100 Hz
Spannungsabfall

$\pm 0,5\%$ vom Bereichsendwert
 $\pm 0,5\%$ von der Ablesung
 $\pm 1\%$ vom Bereichsendwert
 $\pm 0,5\%$ von der Ablesung
1 mV/nA

μ A-Bereiche

Bereichsendwerte	19,98 μ A; 199,8 μ A; 1998 μ A
Messunsicherheit im Frequenzbereich von:	
10 Hz ... 10 kHz	+ 0,5% vom Bereichsendwert - 0,5% von der Ablesung
10 kHz ... 20 kHz	+ 1% vom Bereichsendwert - 1% von der Ablesung
Spannungsabfall	1 mV/ μ A

mA-Bereiche

Bereichsendwerte	19,98 mA; 199,8 mA; 1400 mA
Messunsicherheit im Frequenzbereich von:	
10 Hz ... 100 kHz	+ 0,5% vom Bereichsendwert - 0,5% von der Ablesung
100 kHz ... 200 kHz	+ 1% vom Bereichsendwert - 1% von der Ablesung
Spannungsabfall	1 mV/mA

II-1.5. Hochfrequenzspannung

Messung mit Tastkopf PM 9203	
Frequenzbereich	300 kHz ... 700 MHz
Bereichsendwerte	19,98 mV _{eff} ; 199,8 mV _{eff} ; 1998 mV _{eff}
Kleinste messbare HF-Spannung	2 mV
Frequenzgangfehler zwischen	
300 kHz und 300 MHz	< 0,5 dB
300 MHz und 700 MHz	< 1,5 dB
Messunsicherheit bei Spannungen > 5 mV	
zwischen 300 kHz und 300 MHz	< 1 dB
zwischen 300 MHz und 700 MHz	< 2 dB
Eingangskapazität	< 2 pF
Paralldämpfungswiderstand	von Spannung und Frequenz abhängig zwischen 10 k Ω und 200 k Ω
Messung mit Tastkopf PM 9203 und T-Stück PM 9253	
Frequenzbereich	300 kHz ... 1200 MHz
Messunsicherheit	< + 5 dB - 0 dB

II-1.6. Widerstand

Ω -Bereiche	
Bereichsendwerte	19,98 Ω ; 199,8 Ω ; 1998 Ω
Auflösung	0,01 Ω im 13,99 - Bereich
Messunsicherheit	+ 0,2% vom Bereichsendwert + 0,2% von der Ablesung
Max. Strom	1 mA
Max. Spannung	1,4 V

kΩ-Bereiche

Bereichsendwerte
Messungssicherheit

19,98 kΩ; 199,8 kΩ; 1998 kΩ
+ 0,2% vom Bereichsendwert
+ 0,2% von der Ablesung

Max. Strom
Max. Spannung

5 μA
7 V

MΩ-Bereiche

Bereichsendwerte
Messunsicherheit

19,98 MΩ; 199,8 MΩ; 1998 MΩ
+ 0,3% vom Bereichsendwert } unterhalb
+ 0,2% von der Ablesung } 100 MΩ
+ 2% oberhalb 100 MΩ

Max. Strom
Max. Spannung

5 nA
7 V

II-2. ALLGEMEINE DATEN

II-2.1. Bereichswahl

Bereichsgruppe mit Drucktasten, von Hand.
3 Bereiche innerhalb einer Gruppe automatisch, wahlweise auch von Hand einstellbar.

II-2.2. Temperaturbereich

Für die angegebene Genauigkeit
Temperaturkoeffizient (ausgenommen
HF-Messungen) zwischen -10°C ... 45°C
Typischer Wert

23°C ± 5°C
≤ 200 ppM/°C
≤ 100 ppM/°C

II-2.3. Speisung

Netzspannung
Netzfrequenz
Leistungsaufnahme

Durchgriffskapazität zwischen Netz und
Schaltungsnull
Kapazität zwischen LO und Gehäuse
Zulässige Gleichspannung zwischen Null und
Schaltungsnull

115 V und 230 V ± 15%
50 ... 60 Hz
22 VA

< 50 pF
1500 pF
max. 500 V

II-2.4. Gleichtaktstörspannungsunterdrückung für DC

120 dB

II-2.5. Zeitverhalten

Integrationszeit
Integrationszeit ohne Bereichumschaltung für DC
für AC
Bereichumschaltung

100 ms
ca. 750 ms
ca. 2 s
ca. 100 ms

II-2.6. Analog Ausgang

Spannung pro Digit	3.5 mV
Max. Ausgangsspannung	7 V
Quellenwiderstand	5 k Ω $\pm$ 0,25%

II-2.7. Digitalausgang

Mit Zusatzprinteinheit PM 9221.

II-3. MECHANISCHE DATEN

Abmessungen	Breite	305 mm
	Höhe	145 mm
	Tiefe	270 mm
Gewicht		7 kg.

III. Zubehör

- Netzanschlusskabel
- Sicherung
- Klemmhalter (Abb. 1B, seite 50)
- Imbusschlüssel (2,5 mm)
- Bezeichnungsschild für Netzspannung
- Messkabel komplet mit Messkopfhalter, 2 Messhacken, Messkopfspitze (Abb. 1A, seite 50)
- Anleitung

ZUSÄTZLICH, AUF BESTELLUNG LIEFERBAR

Hochspannungs-Messkopf PM 9246 (Abb. 2, seite 50)

Mit dem hochspannungs Messkopf PM 9246 können Gleichspannung bis 30 kV gemessen werden. Der PM 9246 kann benutzt werden für Messinstrumenten mit einer Eingangsimpedanz von 100 M Ω , 10 M Ω und 1,2 M Ω (umschaltbar).

TECHNISCHE DATEN

Zulässige Spannung	30 kV
Abschwächung	1000 x
Eingangsimpedanz	600 M Ω $\pm$ 5%
Fehlergrenze	$\pm$ 3% für Messinstrumenten mit Eingangsimpedanz von 100 M Ω und 10 M Ω
	$\pm$ 5% für Messinstrumenten mit Eingangsimpedanz von 1,2 M Ω

Achtung: Für eine gute Erdverbindung muss gesorgt werden.

- HF-Tastkopf PM 9203 (siehe Abschnitt XIV)
- HF-T-Stück PM 9253 (siehe Abschnitt XIV)
- Zusatzeinheit für Digitalausgang PM 9221 (siehe Abschnitt XV)
- 3 E Einschubkasten PM 9706 (Abb. 3, Seite 50)

PM 9706 ist ein universales 3 E-PIT-Gehäuse, mit einer Breite von 6 Modul. Es enthält Seitenwände mit Handgriffen, Füßen, Aufstellbügel, Ober- und Unterplatte, Führungsschienen und einen Kunststoff-Kabelkasten, in welchem sich zwei Eckbügel für 19"-Gestelleinbau befinden.

- Untereinheit PM 9722

PM 9722 ist eine leere Einheit für ein 3 E-PIT-Gehäuse mit einer Breite von 2 Modul, um den leeren Raum auszufüllen, wenn das PM 2421 in den Einschubkasten PM 9706 eingebaut wird.

- Untereinheit PM 9721

PM 9721 ist eine leere Einheit für das 3 E-PIT-Gehäuse mit einer Breite von 1 Modul. Zwei Stück PM 9721 können benutzt werden an Stelle des PM 9722.

IV. Wirkungsweise

IV-1. BLOCKSCHALTBILD (Abb. 4, Seite 54)

Die Messart sowie die Bereichsgrößenordnung wird am PM 2421 mit Drucktasten gewählt. Entsprechend dieser Einstellung geschieht das Zusammenschalten der Funktionseinheiten in der Anordnung, die für die Lösung der gewählten Messaufgabe richtig ist. Man kann in diesem Zusammenhang folgende Funktionen unterscheiden:

a. Zusammenschaltung der Funktionseinheiten.

Der AC bez. DC-Verstärker, DC-Stromgenerator und der 300 kHz Oszillator werden je nach Messart mit dem entsprechenden Eingang verbunden und an den Analog-Digital-Converter geschaltet, wobei verschiedene Kombinationen möglich sind (siehe unter Punkt IV-2). Ausserdem wird bei AC und HF-Messungen der niederohmige Spannungsteiler zwischen zwei AC-Verstärkern eingeschaltet, und bei DC und Widerstandsmessungen an den Ausgang des DC-Verstärkers.

b. Vorwahl des groben Messbereiches.

Bei Spannungs- oder Strommessungen wird eine Anpassung des Eingangssignales zu den Eingängen gemäss des gewählten Bereiches vorgenommen. Diese Vorwahl geschieht in 10³ Stufen, wie z.B. für nA, μ A und mA.

c. Hilfsfunktionen.

Der Drucktastenschalter erfüllt verschiedene Hilfsfunktionen, wie das Kurzschliessen der Strommessklemmen bei Spannungs- und Widerstandsmessung. Er gibt die Polaritätsanzeige bei DC-Messungen frei, sorgt für das Sinuszeichen bei AC und HF-Messungen, und löscht das Vorzeichen bei Widerstandsmessungen aus.

IV-1.1. DC- Verstärker

Dieser dient für die Messung von Gleichspannung und Gleichstrom, sowie zur Messung der Widerstandsgrößen. Bei der HF-Messung wirkt er als sehr empfindlicher Regelverstärker. Dieser DC-Verstärker ist chopperstabilisiert und besitzt eine innere Gleichspannungsverstärkung von über 5×10^7 .

IV-1.2. AC-Verstärker und AC - DC - Umwandler

Der AC-Verstärker und der AC to DC-Converter sind bei Messungen von Wechselstrom- bzw. Wechselspannungsgrößen sowie bei der HF-Messung im Betrieb. Der erste AC-Verstärkerteil ist ein Impedanzwandler, welcher den niederohmigen Spannungsteiler speist. Dem zweiten Spannungsverstärker folgt der eigentliche AC to DC-Converter, der eine gegen Erde symmetrische Ausgangsspannung liefert.

Diese, der Eingangswechselgrösse genau proportionale Gleichspannung wird mit einem DC-Differenzverstärker so weiterverarbeitet, dass am Ausgang eine Spannung gegen das Schaltungsnulld zur Verfügung steht.

IV-1.3. Stromgenerator

Der Stromgenerator liefert einen konstanten Gleichstrom von 1 mA, welcher für die Widerstandsmessung benutzt wird. Zur Vermeidung langer Messzeiten ist die Ausgangsspannung begrenzt.

IV-1.4. HF-Teil

Der Hochfrequenzteil enthält einen L-C-Oszillator, der mit einer Frequenz von 300 kHz schwingt. Die Ausgangsspannung von 300 kHz wird durch einen Regulator derart gesteuert, dass sie gleich gross wie die zu messende Hochfrequenzspannung ist. Das Prinzip der HF-Messung ist unter Punkt IV-2.3 in diesem Kapitel näher erläutert.

IV-1.5. Spannungsteiler

Innerhalb des vorgewählten Grobbereiches erfolgt eine in drei Dekaden abgestufte Spannungsteilung. Dieser aus Präzisionswiderständen aufgebaute, niederohmige Spannungsteiler wird automatisch mit Reed-Relais geschaltet. Die Schaltimpulse für die Relaissteuerung stammen aus dem Digital-Teil. Die Umschaltung auf den entsprechenden Messbereich erfolgt automatisch, kann aber auch von Hand ausgeführt werden.

IV-1.6. Digitalteil

Der Analog-Digitalkonverter wandelt die an seinem Eingang liegende Analoggrösse in digitale Form um. Die Resultate der digitalen Information werden zuerst gespeichert, und dann an den Anzeigeteil übertragen. Solange keine Messwertänderung stattfindet, wird stets derselbe Messwert angezeigt. Sobald eine Änderung eintritt, wird diese angezeigt und bleibt bis zur nächsten Messwertänderung konstant erhalten. Ist der Messwert gleich oder grösser als 1998, zeigt die Signallampe "OVERLOAD" an, dass der Bereichsendwert überschritten ist.

IV-1.7. Speisung

Stabilisierte Speiseschaltungen versorgen die verschiedenen Schaltkreise mit den benötigten Spannungen. Die Gleichspannungen von + 15 V und -15 V dienen gleichzeitig als Referenz für die Analog-Digitalumwandlung. Sämtliche Speiseschaltungen sind kurzschlussfest und kurzzeitig überlastbar.

IV-2. FUNKTIONSSCHALTBILD

Die Zusammenschaltung der verschiedenen Einheiten ist auf dem Funktions-Blockschaltbild Abb. 5 ersichtlich. Je nach Messaufgabe werden die einzelnen Einheiten durch die Stellung der Drucktastenschalter kombiniert. Im folgenden Abschnitt soll eine Übersicht über die Zusammenhänge der verschiedenen Messarten gegeben werden.

IV-2.1. Gleichspannungs- bzw. Gleichstrommessung (Abb. 6, Seite 58)

Der Eingangsspannungsteiler 1:1000 teilt die Spannung im Messbereich "V" derart, dass die Ausgangsgrösse für den Messkreis derjenigen des "mV"-Bereiches entspricht und vom Gerät verarbeitet werden kann.

Bei Strommessung wird die Spannung an den Shuntwiderständen erfasst.

Die Gleichspannungsmessung basiert auf den durch Gegenkopplung bestimmten Verstärkungsgrad eines chopperstabilisierten DC-Verstärkers und Auswertung des Analogausganges durch den Analog to Digital-Converter. Störende Wechselspannungen, die dem Mess-Signal überlagert sind, werden durch ein Tiefpassfilter unterdrückt. Das am Eingang des DC-Verstärkers vorhandene Signal wird durch den Verstärker invertiert. Die Spannungsverstärkung der Schaltung hängt praktisch nur von dem Spannungsteiler und von den Widerständen im Gegenkopplungskreis ab, weil die innere Verstärkung sehr hoch ist.

Bei direktem Eingang (mV), ist die Spannungsverstärkung 3,5-fach (oberster Relaiskontakt geschlossen), bei Teilung 10:1 (mittlerer Kontakt geschlossen) 35-fach, und bei Teilung 100:1 (unterer Kontakt geschlossen) 350-fach. Eine Eingangsspannung von 10 mV erzeugt bei der höchsten Empfindlichkeit (Verstärkung 350-fach) eine Analog-Ausgangsspannung von 3,5 V. Diese Spannungsgrösse entspricht einer Anzeige im Digitalteil von 10.00 (Taste mV gedrückt).

IV-2.2. Wechselspannungs- bzw. Wechselstrommessung (Abb. 7, Seite 58)

Das zu messende AC-Signal wird in den mV-Bereichen dem Eingang des Impedanzwandlers zugeführt. In den V-Bereichen sowie in den Strombereichen werden dieselben Spannungsteilerelemente, bzw. dieselben Shunts verwendet wie in den entsprechenden DC-Bereichen. Schaltungstechnisch sind somit alle AC-Messungen auf Spannungsmessungen in den mV-Bereichen zurückgeführt.

Am Eingang des Impedanzwandlers sperrt ein Kondensator eine ev. vorhandene Gleichspannung. Wechselspannungen werden im Impedanzwandler, der eine Verstärkung von 1 aufweist, übertragen, wobei die Ausgangsimpedanz dieser Einheit sehr klein ist.

Der am Impedanzwandler angeschlossene Spannungsteiler wird auch für DC- und Widerstandsmessungen benutzt, wobei jedoch bei der AC-Messung die Empfindlichkeitsabstufung umgekehrt ist. Bei der obersten geschlossenen Kontaktstellung ist die Ausgangsspannung am Analog-Ausgang demzufolge 3,5 V, wenn der Effektivwert einer sinusförmigen Eingangsspannung 10 mV beträgt. Dem Spannungsteiler des automatischen Bereichumschalters folgt ein AC-Verstärker mit hoch-ohmiger Eingangsimpedanz. Der AC to DC-Converter enthält einen Breitbandverstärker mit grosser Bandbreite und hoher Leerlaufverstärkung, sowie ein Doppelweggleichrichternetzwerk im Gegenkopplungskreis.

Mittels diesen schaltungstechnischen Massnahmen wird eine Mittelwertgleichrichtung von hoher Linearität erzielt. Die Ausgangsspannung des AC to DC-Converters ist in Bezug auf Schaltungsnull symmetrisch und enthält Wechselspannungskomponenten. Das Signal wird deshalb gefiltert und einer Impedanzwandlerstufe zugeführt. Der folgende Differenzverstärker setzt das Signal gegen das Schaltungsnull um und wird durch den Digital-Teil sowie den Analog-Ausgang ausgewertet.

IV-2.3. Hochfrequenz-Spannungsmessung (Abb. 8, Seite 58)

Die Spannungen im Hochfrequenzbereich werden nach dem Prinzip des Kompensationsverfahrens gemessen. Dazu wird die zur Kompensation benötigte Spannung in der Amplitude automatisch so geregelt, dass die Eingangs- und Kompensationsspannung die gleichen Werte aufweisen.

Im Tastkopf sind vier gepaarte Dioden vorhanden, wobei sich deren zwei im HF-Eingangskreis und die anderen zwei im Kompensationskreis befinden. Der von den Dioden gelieferte Gleichstrom steuert den DC-Verstärker, der ohne Gegenkopplung mit sehr grosser Verstärkung arbeitet. Die Ausgangsspannung des DC-Verstärkers steuert den Oszillator und dessen Regelverstärker derart, dass die als Kompensationsspannung wirkende Oszillatorspannung gleich gross ist wie die Eingangs-HF-Spannung. Die Polarität der gleichgerichteten HF-Spannung und diejenige der gleich gross sind, ist die resultierende Ausgangsgleichspannung Null.

Am Eingang des AC to DC-Converters entsteht jetzt ein 300 kHz-Signal, dessen Spannung den gleichen Wert wie das zu messende HF-Signal aufweist. Diese Kompensationsspannung von 300 kHz wird über den AC to DC-Converter mit dem Digital-Teil auf dieselbe Weise gemessen wie AC-Spannung in den mV-Bereichen.

Mit dieser Methode werden nachteilige Eigenschaften von den Gleichrichterdioden im Eingangskreis weitgehend ausgeschaltet, indem Dioden verwendet werden, welche dieselben Eigenschaften aufweisen wie diejenigen im Kompensationskreis.

IV-2.4. Widerstandsmessung

Die Widerstandsmessung in den Ohm-Bereichen erfolgt nach dem Prinzip der Spannungsabfallmessung am unbekannten Widerstand. Ein Stromgenerator liefert den für diese Messung erforderlichen konstanten Strom von 1 mA, welcher durch den Prüfling fliesst. Die am Widerstand abfallende Spannung ist proportional dem Widerstandswert und wird als Messgrösse erfasst und durch den Gleichspannungs-Messkreis ausgewertet und angezeigt (Abb. 9, Seite 59).

In den k Ω und M Ω -Messbereichen fliesst der Strom des Stromgenerators durch einen 6,98 Ohm-Widerstand (Abb. 10, Seite 59). Dadurch entsteht eine Spannungsquelle von 6,98 mV, und der zu messende Widerstand im Gegenkopplungskreis ändert die Verstärkung des DC-Verstärkers.

Die Spannung am Analog-Ausgang hängt von der Stellung des Spannungsteilers ab und ist genau proportional zur Grösse von R_X . Im Steuerpfad des DC-Verstärkers liegt der Widerstand R_1 . Dieser Widerstandswert definiert die $k\Omega$, bzw. $M\Omega$ -Bereiche, indem sich der Strom in Gegenkopplungskreis durch R_X auf den von R_1 gegebenen Wert einstellt. Die am Ausgang des Verstärkers auftretende Spannung wird durch den Analog to Digital-Converter erfasst und angezeigt.

IV-2.5. Digitalteil (Abb. 12, Seite 64)

Zur Digitalisierung der Analog-Signale wird in diesem Gerät ein Integrationsverfahren angewendet. Das analoge Eingangssignal gelangt über Vorwiderstände und Entladeschalter an den Integrator, welcher einen Ausgangsimpuls liefert, dessen Länge proportional zur Messgrösse ist. Die prinzipielle Funktionsweise dieses Integrators ist im folgenden Abschnitt etwas näher beschrieben. Abb. 11, Seite 59 zeigt zur Erläuterung eine graphische Darstellung des Spannungsverlaufes in Funktion der Zeit während der Lade- und Entladephase.

Im Vorgang des Integrationsablaufes kann man zwei Hauptzustände unterscheiden, die wir als Aufwärtsintegration (erster Schritt) und Abwärtsintegration (zweiter Schritt) bezeichnen. Im ersten Schritt (Start) wird dem Integrator ein Strom zugeführt, welcher der Eingangsspannung proportional ist (S_1 geöffnet, S_2 und S_3 geschlossen). Am Ausgang liefert der Integrator eine linear mit der Zeit ansteigende Spannung, deren Richtung von der Polarität, und deren Steigung von der Grösse der Eingangsspannung abhängig ist. Die Integrationszeit wird durch Abzählen von 1000 Clockimpulsen bestimmt.

Während dieser Zeitspanne läuft die Aufwärtsintegration und ladet den Kondensator C402 auf. Am Ende des ersten Schrittes wird die Polarität der Integrationsspannung festgestellt und angezeigt. In diesem Augenblick liefert der Zähler den Übertragsimpuls, der zur Einleitung der Abwärtsintegration führt und gleichzeitig den Zähler auf Null stellt.

Im zweiten Schritt wird der Integrator mit einem konstanten Strom gegen Null entladen (S_1 geschlossen, S_2 oder S_3 geöffnet, abhängig von der Polaritätsentscheidung im ersten Schritt). Die Geschwindigkeit der Entladung ist durch den Entladestrom und damit durch die Referenzspannung gegeben und ist deshalb konstant. Die Zeit wird durch Abzählen von Clockimpulsen gemessen; sie ist direkt proportional zu der während dem ersten Schritt angelegten unbekannten Eingangsspannung.

Die Integrationselemente und der Clockgenerator werden für beide Schritte verwendet; deshalb haben Änderungen der Temperatur sowie Langzeitstabilität und Absolutwerte keinen Einfluss auf die Messgenauigkeit. Diese wird in erster Linie durch die Genauigkeit der Referenzspannung bestimmt. Gegen überlagerte Wechselspannungen ist dieses Verfahren auch ohne Verwendung von Filtern unempfindlich, indem überlagerte Wechselspannungen integriert werden, d.h. es entsteht eine Mittelwertbildung.

Sobald die Spannung am Integratorkondensator C402 im Entladevorgang den Nullpunkt durchläuft, schliesst das Gate und der Inhalt des Zählers wird dem Speicher übertragen und angezeigt. Der Zähler steuert auch die Bereichsautomatik, welche drei verschiedene Bereiche einschaltet. Ein Messwert von > 1998 Einheiten bewirkt die Wahl des nächsthöheren Bereiches. Wenn im obersten Bereich der Messwert erneut > 1998 ist, leuchtet zusätzlich die Signallampe "OVERLOAD" auf und zeigt an, dass die Mess-Spannung ausserhalb der erlaubten Grenze liegt, und das angezeigte Resultat nicht mehr verlässlich ist. Wird eine Anzeige von 180 Einheiten nicht erreicht, schaltet die Automatik auf einen empfindlicheren Bereich um. Der gewählte Bereich ist durch die Kommastellung in den Anzeigerhaken gekennzeichnet. Bei jedem Schritt der Bereichsautomatik wird durch den Delay-FF der Start für die nächste Messung um 100 ms verzögert. Die Vorverstärker der AC, DC und HF-Stufen stellen sich in dieser Zeit auf den neuen Messwert ein.

V. Installation

GEBRAUCHSANWEISUNG

V-1. Einstellen auf die örtliche Netzspannung

Am Gerät muss vor Inbetriebnahme kontrolliert werden, ob dessen Anschlussspannung dem Wert der Netzspannung entspricht. Die bei Auslieferung ab Fabrik eingestellte Spannung ist auf der Rückseite des Gerätes mit einem Bezeichnungsschild gekennzeichnet (230 V oder 115 V). Bei diesen Spannungswerten sind Abweichungen von $\pm 15\%$ zulässig; die Sicherung VL1 soll folgenden Stromwert aufweisen:

Nennwert	Spannungsbereich	Sicherung VL1
230 V	200 ... 264 V	160 mA träge
115 V	100 ... 132 V	250 mA träge

Die Umstellung auf den andern Spannungsbereich geschieht durch Umlöten von 2 Kurzverbindungen am Netztransformator. Das Gerätechassis ist zu diesem Zweck an den beiden Verschlussgriffen aus dem Gehäuse herauszuziehen. (siehe Abschnitt VIII-1)

VORSICHT, DAS GERÄT DARF NICHT ANGESCHLOSSEN SEIN.

Die Kurzverbindungen müssen für den betreffenden Spannungsbereich gemäss Abb. 13, Seite 65 eingelötet sein.

Nach der Umlötung auf den neuen Spannungswert ist das Bezeichnungsschild auf der Geräterückseite durch dasjenige mit der entsprechenden Spannungsangabe zu ersetzen.

Netzanschluss:

Das Gerät ist mit dem mitgelieferten dreiadrigen Netzkabel an eine Steckdose mit Schutz Erde anzuschliessen.

V-2. Erdung

Ist das Gerät über das 3 adrige Netzkabel mit dem Netz verbunden, so liegt das Gehäuse an Schutz Erde. Wenn aus Sicherheitsgründen eine Erdung des Messgerätegehäuses erwünscht ist (z.B. bei der Messung von hohen Spannungen), kann das Gerät an der auf der Rückseite befindlichen Erdungsschraube über eine separate Leitung geerdet werden (Abb. 14, Seite 65).

Das Gerät enthält einen speziellen Netztransformator, dessen Primärwicklung beidseitig durch Abschirmungen eingeschlossen ist. Diese Abschirmungen sind mit der Schutz Erde verbunden, so dass kapazitive Erdströme von der Primärwicklung über die Abschirmung auf die Schutz Erde abfliessen.

Die maximal zulässige Spannung zwischen dem Messeingang "LO" und dem Gehäuse beträgt 500 V DC.

Bezüglich der Erdung des Messgerätes sind die entsprechenden örtlichen Vorschriften zu beachten.

V-3. Zusammenbau

Das Gerätechassis des PM 2421 kann an Stelle des 4-Modul-Gehäuses in ein 6-Modul-Gehäuse (PM 9706) eingebaut werden. Der zusätzliche Raum in diesem Gehäuse bietet Platz für weitere Apparate-Einheiten des 3 E-Modularsystems, die im Zusammenhang mit dem Digitalvoltmeter stehen, oder auch unabhängig desselben verwendet werden können. Dieses 6-Modul-Gehäuse entspricht der 19"-Gestellbreite und kann in ein Rackgestell eingebaut werden. Wenn der zusätzliche Raum nicht verwendet wird, kann dieser durch ein leeres Blindfront-Einschubchassis abgedeckt werden.

Für den Umbau des Gerätes in Gestellausführung ist wie folgt vorzugehen :

- Hellgraue Kunststoff-Kabelkappe des PM 9706-Kastens abnehmen und die hierin befindlichen Eckbügel herausnehmen.
- Die 4 Schrauben in den Seitenplatten herausdrehen.
- Seitenplatten vorne etwas anheben und die darunter befindlichen Kunststoffplatten entfernen; die Eckbügel können in dem jetzt freien Raum angebracht werden.
- Seitenplatten anbringen und das Ganze mit den Schrauben befestigen.
- Vier Füße entfernen.
- Die erforderliche Anzahl Führungsschienen an Ober- und Unter-Querbalken montieren. Die betreffenden Löcher in den Querbalken sind mit Gewinde versehen.
- PM 2421 Chassis aus dem 4-Modul-Gehäuse hinausschieben und im 6-Modul-Gehäuse einschieben.
- Leerer Raum mit 1 Einheit PM 9722 oder 2 Stück PM 9721 ausfüllen.
- PM 2421 und PM 9722 verriegeln.

VI. Bedienung

VI-1. Einschalten

Nach dem Anschluss an das Netz und der vorschriftsgemässen Erdung ist das Gerät betriebsbereit. Mit dem Netzschalter "POWER ON" wird das Messgerät eingeschaltet, und die Anzeigeröhren leuchten auf.

VI-2. Wahl der Messart und Anschluss

Die Wahl der Messart erfolgt mit Drucktasten, womit gleichzeitig eine Selektion des groben Messbereiches in 10^3 Dekadenschritten, also 1:1, 1:1000 oder 1:100000 verbunden ist. Innerhalb des gewählten Bereiches findet, je nach Messresultat, eine Umschaltung im Verhältnis 1:1, 1:10, oder 1:100 automatisch statt, mit entsprechender Anzeige der Kommastelle. Die Messarten DC und R (Gleichstrom, bzw. Gleichspannungsmessung und Widerstandsmessung) haben einen gemeinsamen Tastenschalter.

Anschluss

Für den Anschluss des Messkreises sind für Spannung, Strom und Widerstand separate Buchsen vorhanden. Eine gegenseitige Beeinflussung dieser Messkreise ist ausgeschlossen, da die Drucktastenschalter gegenseitig verriegelt sind. Die linksseitige Buchse des I- und V-Anschlusses ist mit dem Schaltungsnullpunkt verbunden und dementsprechend als LO zu verwenden (LOW = niedrig).

Für die Messung von Hochfrequenzspannungen ($> 1 \text{ MHz}$) ist der spezielle Hochfrequenzastkopf (mit T-Stück für koaxiale Leitungen) zu verwenden. Der Anschluss dieses Tastkopfes erfolgt an der 5-poligen Busche "HF" auf der Frontseite.

VI-3. Messwertanzeige und Messbereichumschaltung

Das Messresultat wird durch Kaltkathodenröhren angezeigt, und eine in den Röhren enthaltene Kommastelle definiert das Messergebnis in Bezug auf seinen Dezimalpunkt. Die Umschaltung der Messbereiche erfolgt automatisch, dann aber auch manuell bewerkstelligt werden.

Automatische Umschaltung

Im automatischen Betrieb bekommt der niederohmige Spannungsteiler von der Messwertanzeige abhängige Schaltbefehle. Ist die Anzeige in den weniger empfindlichen Bereichen 180 oder kleiner, wird auf die nächst empfindlichere Bereichsstufe umgeschaltet, und ist die Anzeige 1998 oder höher, wird auf die unempfindlichere Stellung umgeschaltet, sofern diese Möglichkeit besteht. Diese automatische Umschaltung dauert so lange, bis entweder die Anzeige zwischen 180 und 1998 liegt, oder eine der beiden extremen Bereichstellungen eingeschaltet bleibt. Wenn die Anzeige im unempfindlichsten Bereich 1998 oder grösser ist, leuchtet ausserdem die Glimmlampe "OVERLOAD" auf, da die garantierte Messgrenze auch unterhalb 180 stabil vorhanden. Im Anzeigebereich zwischen 1800 und 1998 bleibt der Ablesewert auch dann erhalten, wenn eine grössere Genauigkeit zwischen den Anzeigewerten 1800 und 1998 möglich wäre. Dieser Zustand entsteht dann, wenn die unempfindlichere Stellung durch Übersteuerung oder durch Schwankung der Messgrösse eingeschaltet wurde.

Es ist jedoch leicht möglich, die Automatik zu zwingen, dass die Messung im höchstempfindlichsten Bereich beginnt und die Anzeige bei den entsprechenden Messgrößen zwischen 1800 und 1998 entsteht. Bei Spannungs- und Strommessungen genügt ein kurzes Einschalten des höherliegenden groben Messbereiches mit der entsprechenden Drucktaste; sofern dies möglich ist, oder man kann den Messkreis kurz unterbrechen. Bei der Widerstandsmessung bewirkt ein schnelles Kurzschliessen der "R"-Buchsen die sofortige Umschaltung auf den nächstempfindlicheren Messbereich.

Manuelle Einstellung

Die manuelle Bereichswahl wird in Fällen bevorzugt, wo Serimessungen in einem einzigen Bereich durchzuführen sind. Dadurch erhöht sich für einen Teil der Messwerte die Messgeschwindigkeit, da die Zeiten für die Bereichsumschaltung wegfallen.

Der Umschalter für die manuelle Einstellung befindet sich auf der Rückseite des Gerätes und ist mit einem Schraubenzieher bedienbar. Der Schalter besitzt die vier Schaltstufen 1000, 100, 10 und AUTO. In der Stellung "AUTO" erfolgt die Bereichsumschaltung automatisch, die übrigen Stufen bezeichnen den Messbereich.

VI-4. Polaritätsanzeige

Die Polaritätsanzeige wird bei Gleichspannungs- oder Gleichstrommessungen an einer Kaltkathodenröhre durch ein + oder - Symbol automatisch angezeigt. Diese Anzeige bezieht sich jeweils auf die Anschlussbuchse Hi (High = hoch). Bei der Widerstandsmessung erlischt die Röhre, und bei AC- und HF-Messungen leuchtet ein ~ Symbol auf.

VI-5. DC-Spannungsmessung

Für die Messart DC ist die Drucktaste DC/R zu drücken. Bis zur Eingangsspannung von 1,998 V ist die mV-Taste und bei höheren Spannungen die V-Taste zu betätigen.

Bevor eine Messspannung angelegt ist, beobachten, ob der empfindlichste Messbereich eingeschaltet ist; die Stellung des Dezimalpunktes muss bei 00.00 sein. Der Regler "0" dient für den Nullabgleich; er ist so einzustellen, dass bei offenem Messkreis alle Ziffern 0 zeigen. Dann ist mit dem 0-Regler derjenige Punkt einzustellen, wo die Polaritätsumschaltung kippt, also beim +/- Übergang.

Nach dem Anschluss der zu messenden Spannung an die Buchsen V wird der Messwert und die Polarität der Spannung angezeigt.

Bei der Messung sehr kleiner Spannungen (unterhalb einiger mV) kann es erwünscht sein, die Spannungsquelle ohne die in den Messleitungen auftretenden Thermospannungen zu messen. In diesem Fall ist der 0-Abgleich dann durchzuführen, nachdem man an Stelle der Quelle die Messleitungen kurzgeschlossen hat. Thermospannungen im Messkreis lassen sich jetzt mit dem 0-Regler auskompensieren. Nach dem Abgleich und dem Lösen des Kurzschlusses kann man die zu messende Spannungsquelle anschliessen.

Hochspannungsmessung

Für die Spannungsmessung zwischen 1 kV und 30 kV steht der Hochspannungstastkopf PM 9246 zur Verfügung.

Dieser Tastkopf wird an die Buchsen "V" angeschlossen, wobei der Messpol an HI und der mit "⊥" bezeichnete Pol an LO anzuschliessen ist.

Der vom PM 2421 im V-Bereich angezeigte Wert muss mit dem Faktor 100 multipliziert werden.

VORSICHT ! ! !

Stets zuerst das Erdkabel des Tastkopfes an das Chassis oder an den 0-Pol der Hochspannungsquelle anschliessen, erst dann darf mit dem Tastkopf die Hochspannung berührt werden.

VI-6. AC-Spannungsmessung

Die Messart AC wird mit der Drucktaste "AC" gewählt. Mit den Tasten mV und V sind die groben Spannungsbereiche einstellbar; bis 1,998 V Taste "mV", und bei höherer Spannungen bis max. 500 V die Taste "V" betätigen.

Beim Anschluss der zu messenden Spannung muss beachtet werden, dass das massenähere Messpotential mit der Buchse "LO" verbunden wird. Zur Vermeidung von Messfehlern sind die Messleitungen derart anzuschliessen, dass keine Erdschlaufen entstehen. Die Kapazitätiv durch das Netz induzierten Ströme verursachen in den Messleitungen Spannungsabfälle, welche die Messung beeinflussen können.

Die angelegte Wechselspannung darf einer Gleichspannung bis zu 400 V überlagert sein.

VI-7. Strommessung

Bei Spannungs- und Widerstandsmessungen sind die Buchsen I kurzgeschlossen und liegen auf Schaltungsnull. Für Gleichstrommessung ist die DC/R-Taste zu drücken, und für Wechselströme die AC-Taste.

Entsprechend dem zu messenden Strom ist eine der drei Tasten nA, μ A oder mA zu bedienen. Wenn die Grössenordnung des zu messenden Stromes nicht bekannt ist, empfiehlt es sich, immer zuerst den grössten Messbereich, also mA, einzuschalten, da andernfalls eine Beschädigung der Shuntwiderstände eintreten könnte.

Der Stromkreis ist, speziell bei AC-Messungen, so anzuschliessen, dass sich das massenähere Potential des Stromkreises an der Buchse "LO" befindet. Bei Wechselstrommessung Schleifenbildung vermeiden!

Der Spannungsabfall beträgt 1 mV pro nA, pro μ A oder pro mA, entsprechend dem eingestellten Messbereich. Aus diesem proportionalen Verhalten ist ersichtlich, dass der Spannungsabfall von der angezeigten Ziffer abhängig ist. Wenn bei Strommessungen der Spannungsabfall wesentlich ins Gewicht fällt (bei kleinem Quellenwiderstand) soll die Messung in zwei verschiedenen Bereichen durchgeführt werden; ein eventueller Einfluss des unterschiedlichen Messbereiches ist dann am Messresultat erkennbar. Mit entsprechenden separaten Shuntwiderständen ist es möglich, den Spannungsabfall an den I-Buchsen für alle Stromwerte unterhalb 19,98 mV zu halten.

Zum Schutze der Shuntwiderstände R6 und R10 gegen Überlastung ist der Strommesskreis (über Buchsen I, BU4 und BU5) durch eine Schmelzsicherung von 1,6 A abgesichert (VL3).

Diese Sicherung befindet sich auf der Unterseite an BU5.

VI-8. Widerstandsmessung

Die Widerstandsmessart wird durch Drücken der Taste DC/R eingeschaltet, und für den Anschluss des Prüflings stehen die Buchsen R zur Verfügung. Mit den Drucktasten Ω , k Ω oder M Ω ist der grobe Bereich wählbar. Die Messung erfolgt mit Hilfe von Gleichstrom; dadurch können auch Spulen und Transformatorwicklungen gemessen werden.

WARNUNG ! ! !

Da die Messkreise für Widerstandsmessungen nicht gegen externe Spannungen geschützt sind, ist Vorsicht geboten. Bei einem irrtümlichen Anschluss an eine externe Spannung über ca. 5 V_{eff}, können mehrere Bestandteile im Gerät beschädigt werden.

Der Nullabgleich ist auf folgende Weise vorzunehmen:

Ohmbereiche:

In den Ohmbereichen sind die Buchsen R kurzzuschliessen; mit dem 0-Regler kann die Anzeige auf 0000 eingestellt werden. Wenn der Widerstandswert von Messleitungen nicht mitgemessen werden soll, ist der Kurzschluss am Prüfling vorzunehmen.

Indem man jetzt mit dem DC - 0 - Regler den Anzeigewert auf 0000 einstellt, wird der Widerstandswert der Messleitung in einem kleinen Bereich kompensiert.

K Ω und M Ω -Bereiche:

In diesen Messbereichen liegt die Messschaltung anders (siehe auch Punkt IV-2.4.).

Der Nullabgleich ist hier nicht mehr wesentlich vom Widerstandswert abhängig, sondern von der Verstärkung.

Für den 0-Abgleich ist deshalb die V-Taste zu drücken. Mit dem 0-Regler stellt man jetzt auf 0000 ein. V-Taste wieder lösen und k Ω oder M Ω -Taste drücken. Ein Kurzschliessen der Messbuchsen R ist hier nicht erforderlich.

Bei sehr kleinen Widerstandswerten ist zu berücksichtigen, dass eventuell vorhandene Thermospannungen den Messwert verfälschen können. In solchen kritischen Fällen empfiehlt es sich, den Nullabgleich wie bei "Ohmbereiche" beschrieben, durchzuführen. Der Kurzschluss ist dann direkt am Prüfling vorzunehmen, nicht an den Buchsen.

In den Ohmbereichen fliesst durch den unbekannten Widerstand ein Strom von 1 mA. Durch dieses Verfahren kann man auch Halbleiter in Bezug auf Diodenspannung und Temperaturverlauf bei 1 mA Durchlassstrom paaren. Bei hohen Widerstandswerten (oberhalb 100 M Ω) ist die Messzeit infolge des kleinen Messstromes relativ lang. In diesen Fällen können Brummeinstreuungen unterschiedliche Messwerte verursachen. Zur Vermeidung dieser Erscheinung empfiehlt sich eine Abschirmung des hochohmigen Widerstandes, wobei die Abschirmung mit dem Schaltungsnull zu verbinden ist, z.B. an die Buchse LO des I-Einganges.

VI-9. HF-Spannungsmessung

VI-9.1. Allgemeines

Für Hochfrequenzmessungen bei Frequenzen ≥ 1 MHz steht der Tastkopf PM 9203 sowie ein kapazitiver Abschwächer 100:1 zur Verfügung, und für Messungen an Koaxialleitern das T-Stück PM 9253. Mit diesem HF-Spannungen bis zu Frequenzen von 1200 MHz messbar.

Der HF-Bereich des PM 2421 ist dank dem verwendeten Regelsystem ein sehr empfindlicher HF-Detektor. Dies gilt nicht nur für das zu messende Signal, sondern in gleichem Mass auch für alle Arten von Störspannungen. Signale in der Grössenordnung einiger μ V werden vom PM 2421 detektiert und angezeigt. Hohe Störfeldstärken, wie in der Nähe von benachbarten TV- und Rundfunksendern vorkommen, können zu den obengenannten Störungen Anlass geben.

Andere Störquellen sind z.B. elektrische Maschinen, thyristorgeregelte Motoren u.ä.

Die Eichmöglichkeit des PM 2421 für HF-Messungen wurde für sehr kleine Spannungen konzipiert, um die Diodencharakteristik des Diodenquartestts im Tastkopf zu verbessern.

Die Eichung mit Knopf ADJ. HF kann nötig werden, wenn Spannungen kleiner als 10 mV, mit grösster Genauigkeit zu messen sind. Die Genauigkeit für Spannungen grösser als 10 mV wird durch die Eichung praktisch nicht beeinflusst.

Um die Empfindlichkeit des PM 2421 wirklich auszunutzen, ist es notwendig, empfindliche Messungen in einem Faraday-Käfig durchzuführen. Dort kann auch die Eichung einwandfrei erfolgen.

Die Messung kann z.B. auf nachstehende Weise durch Störspannungen nachteilig beeinflusst werden:

- durch das örtliche Stromversorgungsnetz über den Netztransformator
- als Spannung zwischen Buchse LO und dem Gehäuse (das Gehäuse ist kein idealer HF-Leiter)
- über den Messaufbau, der von einem HF-Feld beeinflusst wird.

Eine wesentliche Verbesserung der oben genannten Störspannungseffekte ist ohne kostspieligen Aufwand kaum möglich. Deshalb werden nachstehende Hinweise gegeben:

- wenn die Empfindlichkeit des Geräts ausgenutzt werden soll, so muss man die Messungen in einem störfeldfreien Raum (Faraday-Käfig) durchführen.
Die Eichung sowie die Messung ist dann einwandfrei durchführbar.
- die Eichung HF-ADJ. ist nur nötig für Messungen ≤ 10 mV, wenn die maximale Genauigkeit erfordert wird.
- die Eichung HF-ADJ. hat keinen merkbaren Einfluss auf die Genauigkeit für Messungen grösser als 10 mV. Das Gerät arbeitet bei höheren Spannungswerten ohne Eichung mit der spezifizierten Genauigkeit.

Der Anschluss des Tastkopfes erfolgt am 5-poligen Stecker auf der Frontseite des Gerätes, und mit der Drucktaste HF wird die Messart eingeschaltet.

Für die Messbereichsgrösse ist die Taste "mV" zu drücken.

Bei Spannungsmessungen unterhalb 10 mV sowie bei grosser Temperaturänderung des Tastkopfes muss eine Eichung vorgenommen werden. Zu diesem Zweck dient der auf der Frontseite befindliche Regler "ADJ", sowie die auf der Geräterückseite befindliche Buchse 300 kHz OUT.

Diese Buchse liefert eine Vergleichsspannung für die Eichung.

VI-9.2. Abgleich

- Gerät einschalten
- Taste AC und Taste mV drücken
- Buchse "300 kHz OUT" auf der Geräterückseite durch ein Anschlusskabel mit Buchse V HI verbinden
- HF-Tastkopf an Buchse "300 kHz OUT" anschliessen, und das Erdungskabel des Tastkopfes mit Buchse LO verbinden
- Den angezeigten Messwert ablesen (eine Wartezeit von ca. 20 s beachten).
- Taste HF drücken
- Mit dem Pot. Meter "ADJ". möglichst genau den vorher abgelesenen Messwert einstellen
- Den Pfeilknopf des Reglers "ADJ" derart befestigen, dass der Peil im abgeglichenen Zustand nach oben zeigt.
- Den Tastkopf von Buchse V HI lösen und die Verbindung zu Buchse 300 kHz OUT entfernen.

Die Eichung des Tastkopfes braucht praktisch nur einmal durchgeführt zu werden. Es ist jedoch bei HF-Messungen stets zu beachten, dass der Pfeil des Reglers senkrecht nach oben zeigt, da sich das Potentiometer hier in der abgeglichen Position befindet (sofern der Pfeilknopf beim Abgleich entsprechend montiert wurde).

Mit einem Gerät mit abgeglichener Eichung darf nur mit demjenigen Tastkopf gemessen werden, mit dem der Abgleich durchgeführt wurde.

Es können jedoch mehrere Geräte auf denselben Tastkopf geeicht werden.

ANMERKUNG: Wird PM 9203 (Tastkopf für HF-Messungen) mit PM 2421 verbunden und kurzgeschlossen, so kann eine Anzeige (< 2 mV) erfolgen, und dadurch, dass bei sehr kleinen Eingangsspannungen ungenügend Signalspannung besteht, um den Regelverstärker einwandfrei funktionieren zu lassen.

VI-9.3. Messung

Spannungsmessungen oberhalb 10 mV und bis zu Frequenzen von 300 MHz lassen sich ohne besondere Massnahmen durchführen. Bei kleinen Eingangsspannungen (unterhalb 5 mV) erfolgt die Anzeige nur langsam.

Eventuelle Störeinflüsse durch HF-Felder können durch Kurzschliessen der Buchsen V (HI und LO) und gleichzeitigen Anschluss der beiden Buchsen R an LO von Buchse V, eliminiert werden.

Bei allen HF-Messungen ist zu beachten, dass das Gehäuse des Tastkopfes mit dem mitgelieferten Erdkabel möglichst gut mit der Messerde verbunden ist.

Die Erdverbindung so kurz wie möglich ausführen, ev. Schaltung abschirmen (HF-Einstreuung von Rundfunksendern möglich).

Für die Messung von Spannungen bei hohen Frequenzen empfiehlt sich bei Verwendung des T-Stückes. Dieses kann mittels Koaxialkabel mit BNC-Connectoren in den Messkreis geschaltet werden. Der HF-Tastkopf wird durch Einschrauben in das T-Stück mit dem HF-Leiter verbunden. Für Messungen im Spannungsbereich von 1,4 V ... 140 V steht ein kapazitiver Spannungsteiler mit einem Teilungsverhältnis von 100:1 zur Verfügung. Da dieser Teiler vor den Messdioden liegt, wird die Kommastellenanzeige nicht mehr stimmen. Der im mV-Bereich angezeigte Messwert muss deshalb mit 100 multipliziert werden.

VI-10. Analog-Ausgang

Im Digital-Eingang werden alle Messspannungen in Gleichspannungswerte derselben Grössenordnung umgewandelt. Die Grösse dieser Gleichspannung innerhalb eines Bereiches ist kontinuierlich proportional zu der Eingangsgrösse, und beträgt für 1 Digit 3,5 mV; daraus resultiert für den Bereichsendwert von 2000 Digit eine Ausgangsspannung von 7 V. Um Rückwirkungen auf die Anzeige bei Kurzschluss des Analog-Ausganges zu vermeiden, ist mit der Analog-Spannungsquelle ein Widerstand von 5,6 k Ω in Serie geschaltet.

Der Ausgang des Analog-Signales befindet sich auf der Rückseite des Gerätes an den beiden Anschlussbuchsen "ANALOG OUT". Damit bietet das PM 2421 die Möglichkeit, das Gerät als empfindlichen Gleichspannungsverstärker oder AC-DC Wandler zu verwenden, sowie für den Betrieb von Registriergeräten zur Aufzeichnung der Messwerte.

I. Introduction

GENERALITES

Le PM 2421 est un multimètre à affichage numérique permettant, dans de très larges plages de valeurs, d'effectuer des mesures en tensions et en courants continus ou alternatifs, sur résistances, et également en tensions HF.

La commutation des gammes, avec déplacement correspondant de la virgule, s'effectue automatiquement; ainsi 9 plages de mesure, chacune dans un rapport de 1 à 100.000, suffisent pour couvrir toutes les possibilités de l'appareil en simplifiant à l'extrême son utilisation.

A une précision exceptionnelle s'ajoutent un facteur de réjection élevé aux signaux d'interférence, et une grande fiabilité.

Les plages de mesures, sélectionnées par boutons-poussoirs, se succèdent dans le rapport de 1000; par exemple nA, μ A et mA pour les plages de courant. La subdivision en gammes de 19,98, 199,8 et 1998 s'effectue, automatiquement, avec déplacement conjoint de la virgule. Ainsi des quantités comprises entre 00,01 et 1998 sont toujours mesurées avec la meilleure résolution possible, sur 3 digits au minimum, sans aucune intervention de l'opérateur. Quand la valeur maximale de 1998 est atteinte, ceci est signalé par un indicateur de surcharge.

La lecture s'effectue sur 3 digits plus 1 digit de dépassement. En outre la polarité est indiquée automatiquement pour les mesures en continu. Le PM 2421 comporte des entrées séparées pour la mesure des tensions, des courants, des résistances et des tensions HF. Les bornes de masse des différentes entrées sont reliées entre elles, mais isolées du châssis de l'appareil.

Les signaux haute fréquence jusqu'à 700 MHz sont mesurés à l'aide de la sonde PM 9203 livrée sur option.

Le PM 2421 comporte une sortie analogique délivrant une tension de 3,5 mV par digit dans toutes les plages de mesures, offrant des applications remarquables en cas d'association à un enregistreur.

Une sortie digitale peut être fournie sur option. Cette sortie est réalisée sous forme de module enfichable et livrée avec le connecteur de sortie.

II. Caractéristiques techniques

Les précisions mentionnées dans les caractéristiques suivantes sont garanties. Les valeurs sans précision ne sont mentionnées qu'à titre indicatif et correspondent aux caractéristiques d'un appareil moyen.

II-1. GAMMES DE MESURE

II-1.1. Tension continues

Gammes "mV"

Fin de gamme	19,98 mV; 199,8 mV; 1998 mV
Résolution	10 μ V dans la gamme 19,98 mV
Résistance d'entrée	1 M Ω
Protection contre des dépassements	500 V DC max.

Gammes "V"

Fin de gamme	19,98 V; 199,8 V; 1000 V
Résistance d'entrée	10 M Ω
Protection contre des dépassements	1000 V DC max.

Précision

De la valeur en fin de gamme	+ 0,1%
De la lecture	- 0,1%

Facteur de rejection de la tension

alternative pour ≥ 50 Hz	80 dB min.
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II-1.2. Courants continus

Gammes "nA"

Fin de gamme	19,98 nA; 199,8 nA; 1998 nA
Résolution	10 pA dans la gamme 19,98 nA
Chute de tension	1 mV/nA

Gammes " μ A"

Fin de gamme	19,98 μ A; 199,8 μ A; 1998 μ A
Chute de tension	1 mV/ μ A

Gammes "mA"

Fin de gamme	19,98 mA; 199,8 mA; 1400 mA
Chute de tension	1 mV/mA

Précision

De la valeur en fin de gamme	+ 0,3%
De la lecture	- 0,2%

II-1.3. Tensions alternatives

Gammes "mV"

Fin de gamme	19,98 mV _{eff} ; 199,8 mV _{eff} ; 1998 mV _{eff}
Résolution	10 μ V _{eff} dans la gamme 19,98 mV _{eff}
Niveau de bruit à l'entrée (court-circuitée)	$< 20 \mu\text{V}$ ($\Delta 2$ digits)
Impédance d'entrée	$1 \text{ M}\Omega // 40 \text{ pF}$
Protection contre des dépassements	pour des fréquences de $\leq 50 \text{ Hz}$: 300 V _{eff} max. pour toutes autres fréquences : 30 V _{eff} max.

Gammes "V"

Fin de gamme	19,98 V _{eff} ; 199,8 V _{eff} ; 500 V _{eff}
Impédance d'entrée	$10 \text{ M}\Omega // 25 \text{ pF}$
Protection contre des dépassements	500 V _{eff} ou 750 V _c

Bande passante

10 Hz à 1 MHz

Précision

- Pour des fréquences de 20 Hz à 300 kHz
de la valeur en fin de gamme $+ 0,3\%$
de la lecture $+ 0,2\%$
- Pour des fréquences de 10 Hz à 20 Hz et de 300 kHz à 1 MHz
de la valeur en fin de gamme $+ 1\%$
- Pour des valeurs > 1400 et des fréquences $\geq 50 \text{ kHz}$
erreur supplémentaire $+ 0,7\%$ de la lecture

Genre de mesure

Redresseur biphasé avec formation de la valeur moyenne pour tensions d'entrée sinusoïdale étalonnées en valeurs effectives.

II-1.4. Courants alternatifs

Gammes "nA"

Fin de gamme	19,98 nA ; 199,8 nA ; 1998 nA
Résolution	10 pA dans la gamme 19,98 nA
Précision: de 10 Hz à 50 Hz	$+ 0,5\%$ de la valeur en fin de gamme $+ 0,5\%$ de la lecture
de 50 Hz à 100 Hz	$+ 1\%$ de la valeur en fin de gamme $+ 0,5\%$ de la lecture
Chute de tension	1 mV/nA

Gammes " μ A"

Fin de gamme	19,98 μ A ; 199,8 μ A ; 1998 μ A
Précision: de 10 Hz à 10 kHz	$+ 0,5\%$ de la valeur en fin de gamme $+ 0,5\%$ de la lecture
de 10 kHz à 20 kHz	$+ 1\%$ de la valeur en fin de gamme $+ 1\%$ de la lecture
Chute de tension	$1 \text{ mV}/\mu\text{A}$

Gammes "mA"

Fin de gamme
 Précision: de 10 Hz à 100 kHz
 de 100 kHz à 200 kHz
 Chute de tension

19,98 mA; 199,8 mA; 1400 mA
 $\pm 0,5\%$ de la valeur en fin de gamme
 $\pm 0,5\%$ de la lecture
 $\pm 1\%$ de la valeur en fin de gamme
 $\pm 1\%$ de la lecture
 $\overline{1}$ mV/mA

II-1.5. Tension H.F.

Avec sonde PM 9203
 Bande passante
 Fin de gamme
 Signal minimum mesurable
 Déviation
 Capacité d'entrée
 Résistance d'amortissement
 Un Té hybride PM 9253 est livrable sur option pour la mesure sur ligne coaxiales.
 Bande passante
 Précision

300 kHz à 700 MHz
 19,98 mV_{eff} ; 199,8 mV_{eff} ; 1998 mV_{eff}
 2 mV
 voir chapitre XIV
 ≤ 2 pF
 $\overline{de}$ 10 k Ω à 200 selon la tension et la fréquence
 300 kHz à 1200 MHz
 $\left. \begin{array}{l} < +5 \text{ dB} \\ -0 \text{ dB} \end{array} \right\} 700 \text{ kHz à } 1200 \text{ MHz}$

II-1.6. RésistancesGammes " Ω "

Fin de gamme
 Résolution
 Précision
 Courant de charge
 Tension maximale

19,98 Ω ; 199,8 Ω ; 1998 Ω
 0,01 Ω dans la gamme 19,98 Ω
 $\pm 0,2\%$ de la valeur en fin de gamme
 $\pm 0,2\%$ de la lecture
 $\overline{1}$ mA
 2 V

Gammes "k Ω "

Fin de gamme
 Précision
 Courant de charge
 Tension maximale

19,98 k Ω ; 199,8 k Ω ; 1998 k Ω
 $\pm 0,2\%$ de la valeur en fin de gamme
 $\pm 0,2\%$ de la lecture
 $\overline{5}$ μ A
 7 V

Gammes "M Ω "

Fin de gamme
 Précision
 Courant de charge
 Tension maximale

19,98 M Ω ; 199,8 M Ω ; 1998 M Ω
 $\left. \begin{array}{l} + 0,3\% \text{ de la valeur en fin de gamme} \\ + 0,2\% \text{ de la lecture} \end{array} \right\} \text{ jusqu'à } 100 \text{ M}\Omega$
 $\pm 2\%$ au-delà de 100 M Ω
 $\overline{5}$ nA
 7 V

II-2. CARACTERISTIQUES GENERALITES

II-2.1. Sélection de gammes

Choix des groupes de gammes par bouton-poussoir.

Sélection automatique de 3 gammes par groupe (réglable manuel possible).

II-2.2. Gamme de température d'utilisation

Pour la précision donnée

$23^{\circ}\text{C} \pm 5^{\circ}\text{C}$

Coefficient de température (sauf pour mesure en H.F.) entre -10°C et $+45^{\circ}\text{C}$

$< 200 \text{ ppm}/^{\circ}\text{C}$

Grandeur typique

$\leq 100 \text{ ppm}/^{\circ}\text{C}$

II-2.3. Alimentation secteur

Tension

$115 \text{ V et } 230 \text{ V} \pm 15\%$

Fréquence

$50 \dots 60 \text{ Hz}$

Consommation

22 VA

Capacité de fuite entre le secteur et le point "froid" du circuit de mesures

$< 50 \text{ pF}$

Capacité entre "LO" et le boîtier

$1,5 \text{ nF}$

Tension continue admissible entre le châssis et le zéro du circuit

500 V max.

II-2.4. Réjection de mode commun

120 dB

II-2.5. Rapport de temps

Temps d'intégration

100 ms

Temps d'intégration sans sélection de gamme

pour couplage direct env. 750 ms

pour couplage capacitif env. 2 s

Sélection de gamme

env. 100 ms

II-2.6. Sortie analogique

Impédance

$5 \text{ k}\Omega \pm 0,25\%$

Tension de sortie

$3,5 \text{ mV}/\text{digit}$ dans toutes les gammes

Précision

identique à celle indiquée pour la fonction considérée

II-2.7. Sortie digitale

Une sortie digitale peut être fournie, sur demande, sous forme d'un module enfichable portant le numéro de code: PM 9221.

II-3. CARACTERISTIQUES MECANIQUES

Dimensions

largeur 305 mm

hauteur 145 mm

profondeur 270 mm

Poids

7 kg

III. Accessoires

- Câble de raccordement au secteur
- Fusible
- Plaquette avec indication de tension secteur
- Jeu de cordon de mesure complet, comprenant un porte-sonde, 2 crochets, une tête de sonde (Fig. 1A, page 50)
- Borne de mesure (Fig. 1B, page 50)
- Clé intravis 2,5 mm
- Notice d'emploi et d'entretien

LIVRABLES SUR COMMANDE

- Sonde HT PM 9246 (Fig. 2, page 50)

La sonde HT PM 9246 est appropriée à la mesure de tensions continues jusqu'à 30 kV.

Il est possible d'utiliser la sonde PM 9246 pour des instruments de mesure avec une impédance d'entrée de 100 M Ω , 10 M Ω et 1,2 M Ω (sélectionnable).

CARACTERISTIQUES TECHNIQUES

Tension maximale	30 kV
Atténuation	1000 x
Impédance d'entrée	600 M Ω $\pm$ 5%
Précision	+ 3% pour instruments avec impédance d'entrée de 100 M Ω et 10 M Ω + 5% pour instruments avec impédance d'entrée de 1,2 M Ω

Attention: Veiller à effectuer une bonne connection de terre.

- Sonde VHF PM 9203 (voir chapitre XIV)
- Té hybride PM 9253 (voir chapitre XIV)
- Module additionnel pour sortie digitale PM 9221 (voir chapitre XV)
- Coffret universel PM 9706 (Fig. 3, page 50)

Le PM 9706 est un coffret universel 3E ayant une largeur de 6 modules. Il comprend les parois latérales avec poignées, les pieds, les équerres escamotables, des plaques inférieure et supérieure, les guides et un compartiment pour câbles en matière plastique dans lequel on trouve deux équerres de fixation pour montage en rack 19".

- Tiroir PM 9722

Le PM 9722 est un bloc vide pour un coffret 3E-PIT ayant une largeur de 2 modules, pour remplir l'espace libre lorsque le PM 2421 est incorporé dans le coffret universel PM 9706.

- Tiroir PM 9721

Le PM 9721 est un bloc vide pouvant contenir le coffret 3E d'une largeur d'un module. Deux PM 9721 peuvent être utilisés à la place du PM 9722.



Fig. 1A

Fig. 1B



Fig. 2

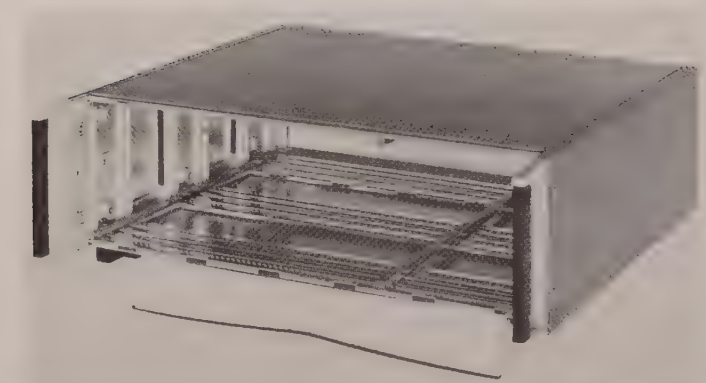


Fig. 3

IV. Principe de fonctionnement

IV-1. SCHEMA SYNOPTIQUE (Fig. 4, page 54)

Les gammes sont sélectionnés sur le PM 2421 à l'aide de boutons-poussoirs.

Selon cette sélection, les blocs fonctionnels sont arrangés de manière que la solution de la mesure souhaitée soit correcte. On pourra des lors différencier les fonctions suivantes:

a. Commutations des blocs fonctionnels

Selon les mesures, les amplificateurs à couplage direct ou capacitif, le générateur de courant continu et l'oscillateur à 300 kHz sont connectés à l'entrée correspondante et branchés au convertisseur analogique digitale, ce qui permet diverses combinaisons (voir point IV-2.4). En outre, lors de mesures en courant alternatif et HF, le diviseur de tension à basse impédance est inséré entre les deux amplificateurs à courant alternatif. Lors de mesures en continu et pour les résistances ce diviseur est inséré à la sortie de l'amplificateur à courant continu.

b. Présélection de la gamme de mesure

Lors de mesures de tension et de courant, le signal d'entrée est adapté aux entrées selon la mesure à effectuer. Cette présélection se fait par plots de 10^3 , (par exemple pour nA, μ A et mA).

c. Fonctions auxiliaires

Le bouton-poussoir remplit certaines fonctions auxiliaires telle que le court-circuit des bornes de courant lors des mesure de tension et de résistance. Il libère l'affichage de polarité pour les mesures en continu, commande le signe "~" pour les mesures en alternatif et lors de mesure de résistance le signe préliminaire est également effacé.

IV-1.1. L'amplificateur à couplage direct

Cet amplificateur est utilisé pour la mesure des courants et des tensions continus et pour la mesure des résistances. Lors de mesure HF, il agit en amplificateur de réglage très sensible. Cet amplificateur à courant continue est stabilisé par un vibreur et possède une amplification de tension continue supérieure à 5×10^7 .

IV-1.2. Amplificateur à courant alternatif et convertisseur "CA-CC"

L'amplificateur à courant alternatif et le convertisseur "CA-CC" sont mis en fonctionnement lors de mesure de courant alternatifs ou de tensions alternatives ainsi que lors de mesure HF. La première partie de l'amplificateur "CA" est un transformateur d'impédance alimentant le diviseur de tension à basse impédance.

Le convertisseur "CA-CC" suit en fait le deuxième amplificateur de tension; le convertisseur fournit une tension de sortie symétrique; cette tension exactement proportionnelle à la valeur d'entrée, est transformée par un amplificateur différentiel "CC" faisant en sorte qu'à la sortie une tension asymétrique par rapport au zéro du circuit soit disponible.

IV-1.3. Générateur de courant

Le générateur de courant fournit un courant continu constant de 1 mA, utilisé pour les mesures de résistances. La tension de sortie est limitée afin d'éviter des temps de mesure trop longs.

IV-1.4. Partie HF

La partie haute fréquence comprend un oscillateur L-C, oscillant à une fréquence de 300 kHz. La tension de sortie de 300 kHz est contrôlée par un régulateur de façon qu'elle soit aussi élevée que la tension HF. Le principe de mesure HF est donné de manière plus approfondie dans le paragraphe 2.3 de ce chapitre.

IV-1.5. Diviseur de tension

Dans le cadre du réglage approché de la gamme présélectionnée, une division de tension se fait en trois étages. Ce diviseur de tension à basse impédance se composant de résistances de précision, est enclenché automatiquement avec des relais. Les impulsions de commutations pour la commande des relais proviennent de la partie numérique. La commutation vers les gammes de mesure correspondantes est automatique, mais peut aussi être manuelle.

IV-1.6. Partie numérique

Le convertisseur analogique digital, transforme les valeurs analogiques se trouvant à son entrée en valeurs numériques. Les résultats de l'information digitale sont d'abord mémorisés et sont ensuite transmis à la partie affichage. Tant qu'il n'y a pas de changement dans la valeur de mesure, la même mesure reste affichée. Dès qu'un changement intervient, il est affiché et se maintient jusqu'à un nouveau changement de valeur. Si la valeur est égale ou supérieure à 1998, la lampe-témoin "OVERLOAD" s'allume.

IV-1.7. Alimentation

Des circuits d'alimentation stabilisée fournissent les tensions nécessaires aux différents circuits. Les tensions continues de +15 V à -15 V servent également de référence à la conversion analogique-digitale. Tous les circuits d'alimentation sont protégés contre les courts-circuits et peuvent être surchargés mais à très courte durée.

IV-2. SCHEMA FONCTIONNEL

Le fonctionnement simultané des différents blocs est visible sur le schéma de fonctionnement fig. 5, page 54. Selon la mesure à effectuer, les différents blocs sont combinés par la position du bouton-poussoir. Le chapitre suivant donne un aperçu des rapports entre les différentes mesures.

IV-2.1. Mesure de tension ou de courant continu (Fig. 6, page 58)

Le diviseur de tension d'entrée 1:1000 divise la tension en gamme de mesure "V", de façon que la valeur de sortie corresponde au circuit de mesure de la gamme "mV" et puisse être transformée par l'appareil. Lors de mesures de courant, la tension est prélevée aux résistances shuntées.

La mesure de tension continue est basée sur la facteur d'amplification déterminée par la contre-réaction d'un amplificateur à courant continu à stabilisation par vibreur et par l'évaluation de la sortie analogique par le convertisseur analogique-digitale.

Des tensions alternatives parasites au signal de mesure, sont éliminées par un filtre passe-bas. Le signal disponible à l'entrée de l'amplificateur à courant continu est inversé par l'amplificateur. L'amplification de la tension du circuit de contre-réaction, parce que l'amplification interne est très élevée.

A l'entrée directe (mV), l'amplification de la tension est 3,5 fois (contact de relais supérieur fermé), lors de la division 10:1 (contact central fermé) de 35 fois et lors de la division 100:1 (contact inférieur fermé) 350 fois.

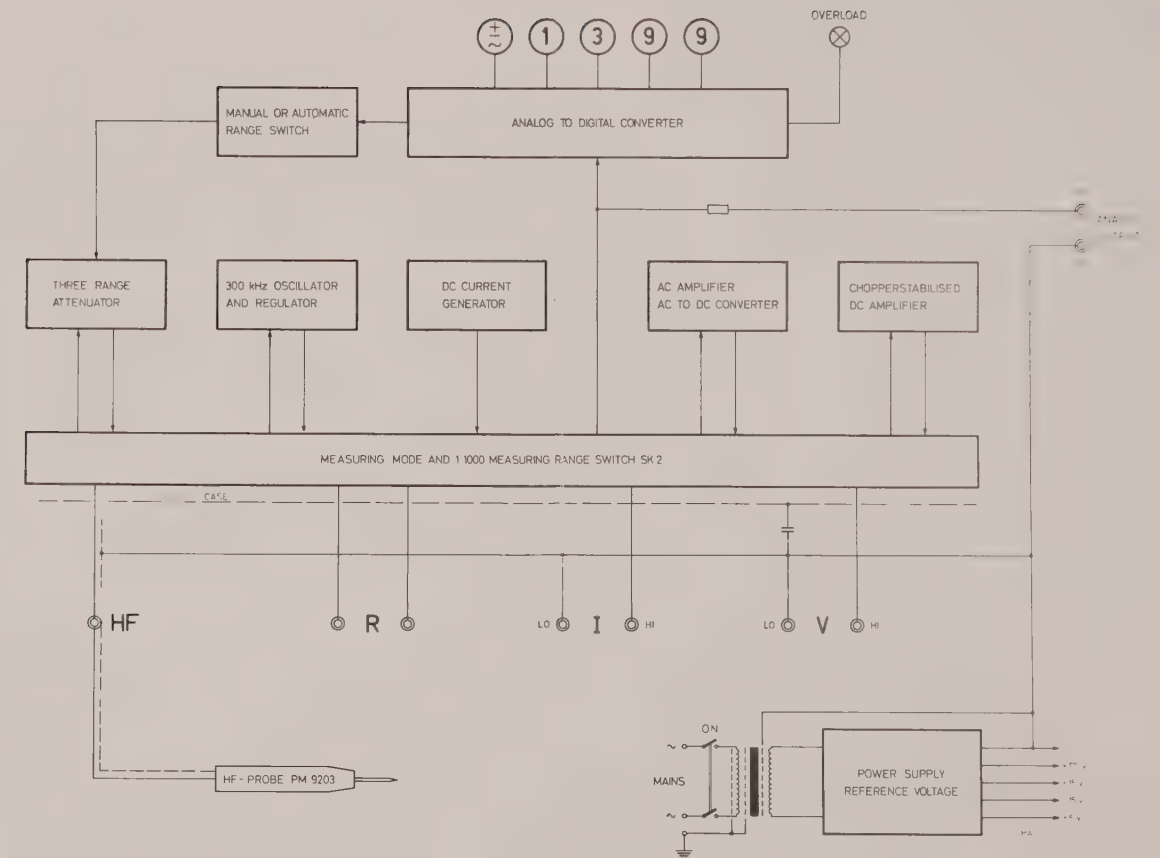


Fig. 4

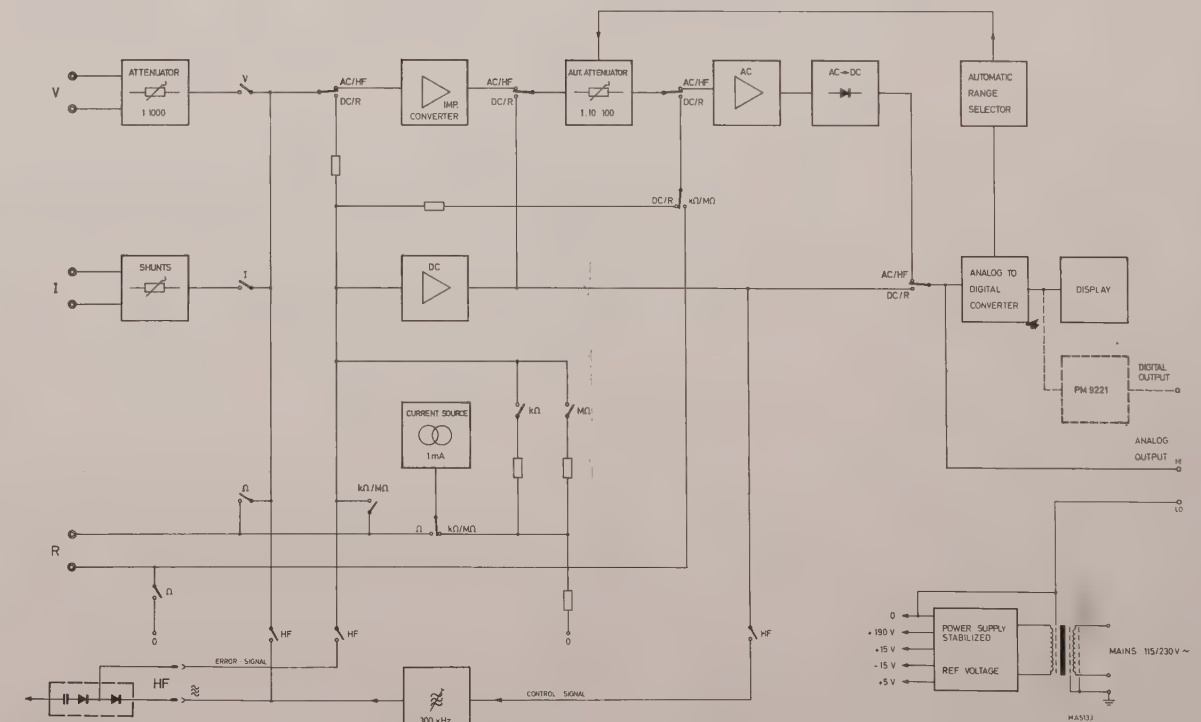


Fig. 5

Une tension d'entrée de 10 mV provoque à la sensibilité extrême (amplification de 350 fois), une tension de sortie analogique de 3,5 V. Cette tension correspond à un affichage dans la partie numérique de 10.00 (la touche mV étant enfoncée).

IV-2.2. Mesure de tension ou de courant alternatifs (Fig. 7, page 58)

Le signal à courant alternatifs à mesurer est amené à l'entrée du transformateur d'impédance dans les gammes "mV". Dans les gammes en "V" ainsi que les gammes de courant, les mêmes éléments diviseurs de tension ou les mêmes shunts sont utilisés que dans les gammes "CC" correspondantes, de sorte que toutes les mesures "CA" peuvent être rapportées aux mesures de tension dans les gammes "mV".

A l'entrée du transformateur d'impédance, un condensateur bloque une tension continue éventuelle. Les tensions alternatives sont reportées dans le transformateur qui effectue une amplification de 1; l'impédance de sortie de ce bloc est très faible.

Le diviseur de tension raccordé au transformateur d'impédance est aussi utilisé pour des mesures de résistance, il faut cependant tenir compte que pour les mesures "CA", la graduation de la sensibilité est inversée. Lorsque le contact supérieur est fermé, la tension de sortie à la sortie analogique résulte en 3,5 V, ceci lorsque la valeur effective présente une tension d'entrée sinusoïdale est de 10 mV.

Un amplificateur "CA" à impédance d'entrée élevée est placé à la suite du diviseur de tension du commutateur de gammes automatique. Le convertisseur CA-CC contient un amplificateur à large bande avec une amplification à vide élevée ainsi qu'un réseau redresseur à double voie dans le circuit de contre-réaction. On obtient un redressement médian de linéarité parfaite. La tension de sortie du convertisseur CA-CC est symétrique par rapport au zéro du circuit et contient des composantes de tension alternative.

C'est pour cela que le signal est filtré et qu'il est amené à un transformateur d'impédance. L'amplificateur différentiel suivant converti le signal en un signal asymétrique par rapport au zéro du circuit et le signal est évalué par la partie numérique ainsi que par la sortie analogique.

IV-2.3. Mesure de tension haute fréquence (Fig. 8, page 58)

Les tensions dans la gamme haute fréquence sont mesurées selon le principe de compensation. La tension nécessaire à la compensation est réglée automatiquement en amplitude de façon que la tension d'entrée et la tension de compensation présentent les mêmes valeurs.

Dans la sonde il y a deux couples de diodes, dont un se trouve dans le circuit d'entrée HF et l'autre dans le circuit de compensation. Le courant continu fourni par les diodes commande l'amplificateur CC, qui fournit une très forte amplification sans contre-réaction. La tension de sortie de l'amplificateur CC commande l'oscillateur et ses amplificateurs de réglage de façon que la tension d'oscillation agissant en tension de compensation est égale à la tension d'entrée HF. La polarité de la tension HF redressée et celle de la tension de compensation redressée sont opposées. Si les deux tensions sont égales, la tension continue qui en résulte est nulle. A l'entrée du convertisseur CA-CC se présente maintenant un signal de 300 kHz dont la tension est pareille au signal HF à mesurer. La tension de compensation de 300 kHz est mesurée de la même façon par le convertisseur CA-CC avec partie numérique que la tension CA dans les gammes mV.

On élimine ainsi largement des caractéristiques désavantageuses des diodes de redressement, puisqu'on utilise des diodes ayant les mêmes caractéristiques que celles du réseau de compensation.

IV-2.4. Mesure de résistance

La mesure de résistance s'effectuant dans les gammes ohmiques se fait selon le principe de la mesure de chute de tension à une résistance inconnue (Fig. 9, page 59). Un générateur de courant fournit un courant constant de 1 mA qui parcourt la résistance à mesurer. La chute de tension à la résistance, est proportionnelle à la valeur de résistance et est prélevée en tant que valeur de mesure; elle est évaluée et affichée par le réseau de mesure de tension continue.

Dans les gammes de mesure $k\Omega$ et $M\Omega$ le courant du générateur parcourt une résistance de $6,98 \Omega$ (Fig. 10, page 59). Il en résulte une source de tension de $6,98 \text{ mV}$, et la résistance à mesurer dans le réseau de contre-réaction modifie la valeur de l'amplification de l'amplificateur CC. La tension à la sortie analogique dépend de la position du diviseur de tension et est exactement proportionnelle à la valeur R_X . Dans la trace de commande de l'amplificateur CC, il y a une résistance $R1$. Cette valeur de résistance définit les gammes $k\Omega$ ou $M\Omega$, du fait que le courant dans le circuit de contre-réaction est réglé par la valeur produite par $R1$ provoquée par R_X . La tension présente à la sortie de l'amplificateur est prélevée par la partie analogique du convertisseur numérique et affichée.

IV-2.5. Partie digitale (Fig. 12, page 64)

La transformation des signaux analogiques en signaux numériques s'effectue par un procédé d'intégration dans cet appareil. Le signal d'entrée analogique est appliqué à l'intégrateur par l'intermédiaire des résistances préliminaires; cet intégrateur fournit une impulsion de sortie dont la longueur est proportionnelle à la valeur de mesure. Le principe de fonctionnement de cet intégrateur est décrit de façon un peu plus approfondie dans le paragraphe suivant. La fig. 11, page 59 montre pour plus de clarté un graphique du processus d'intégration on peut distinguer deux situations majeures, que nous nommerons intégration ascendante (première phase) et intégration descendante (deuxième phase). Dans la première phase (départ) un courant, qui est proportionnel à la tension d'entrée, est appliquée à l'intégrateur (S1 ouvert, S2 et S3 fermés). A la sortie l'intégrateur fournit une tension linéaire ascendante avec le temps dont le sens dépend de la polarité et l'ascension dépend de la valeur de la tension d'entrée. Le temps d'intégration est déterminé par décompte de 1000 impulsions d'horloge. Pendant ce temps l'intégration ascendante se poursuit et charge le condensateur C402. A la fin de la première phase est déterminée la polarité de la tension d'intégration et celle-ci affichée. A ce moment, le compteur fournit l'impulsion de transmission qui provoque l'intégration descendante et remet à zéro le compteur en même temps. Dans la deuxième phase l'intégrateur est déchargé à zéro par un courant constant (S1 fermé, S2 ou S3 ouvert selon la polarité dans la première phase). La vitesse de la décharge est déterminée par le courant de décharge et de ce fait par la tension de référence et reste donc constante. Pendant toute la durée, des impulsions d'horloge sont produites; cette durée est directement proportionnelle à la tension d'entrée inconnue établie lors de la première phase.

Les éléments d'intégration et le générateur d'impulsions d'horloge sont utilisés pour les deux phases; c'est pour cela que des variations de la température ainsi que la stabilité de longue durée et les valeurs absolues n'ont aucune influence sur la précision de la mesure. Elle est déterminée avant tout par la précision de la tension de référence. Ce processus même sans utilisation de filtres est insensible à des tensions alternatives superposées, du fait que celles-ci sont intégrées, c-à-d, que se forme une valeur médiane.

Dès que la tension sur le condensateur de l'intégrateur C402 dépasse le zéro lors du processus de décharge, la porte se ferme et le contenu du compteur est transmis à la mémoire, il est aussi affiché. Le compteur commande aussi le sélecteur automatique, qui commute trois gammes différentes. Une valeur de mesure de ≥ 1998 unités, influence le choix de la gamme suivante. Si dans la gamme supérieure, la valeur de mesure est de nouveau ≥ 1998 , la lampe-témoin "OVERLOAD" s'allume et indique que la tension de mesure se situe en dehors des limites admissibles et que le résultat affiché n'est plus certain. Si l'on atteint pas un affichage de 180 unités, le sélecteur automatique commute vers une gamme plus sensible. La gamme choisie est caractérisée par la position de la virgule sur le tube d'affichage. A chaque étape du sélecteur automatique, on retarde le départ par de Delay-FF de 100 ms pour la mesure suivante. Les amplificateurs préliminaires des étages CA, CC et HF se mettent pendant ce temps sur la nouvelle valeur de mesure.

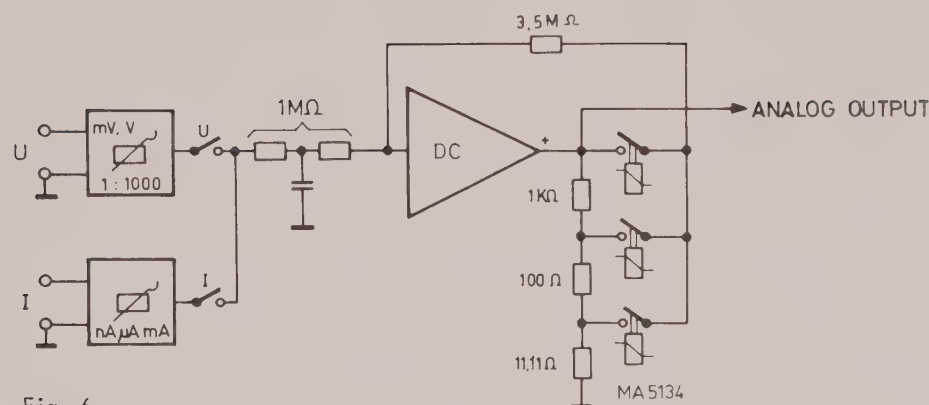


Fig. 6

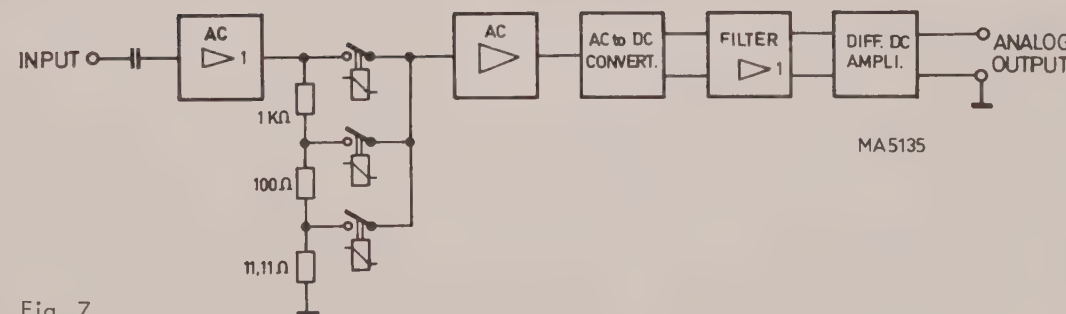


Fig. 7

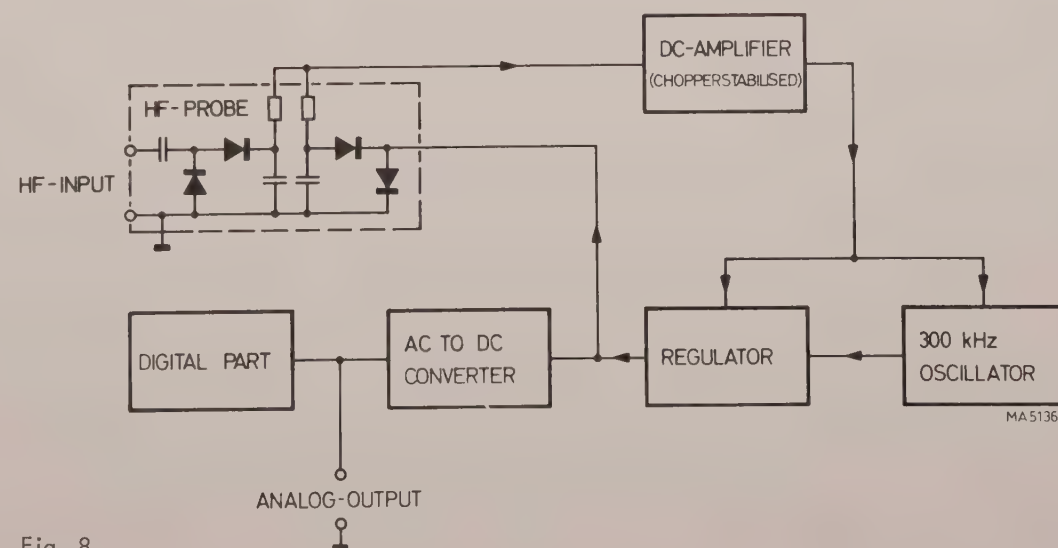


Fig. 8

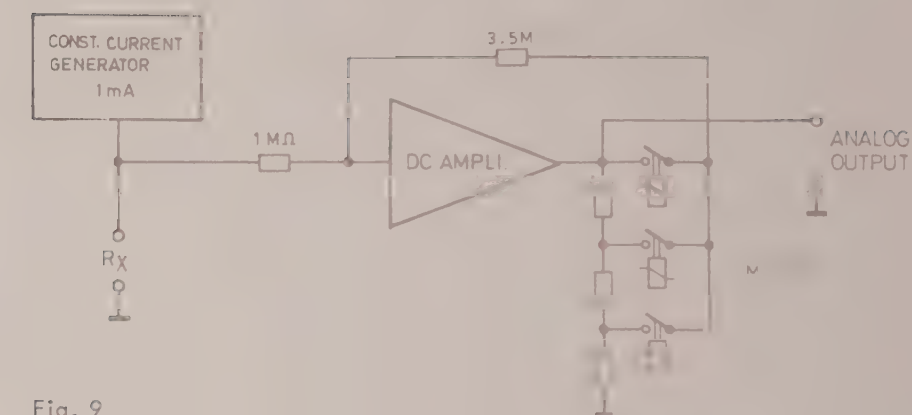


Fig. 9

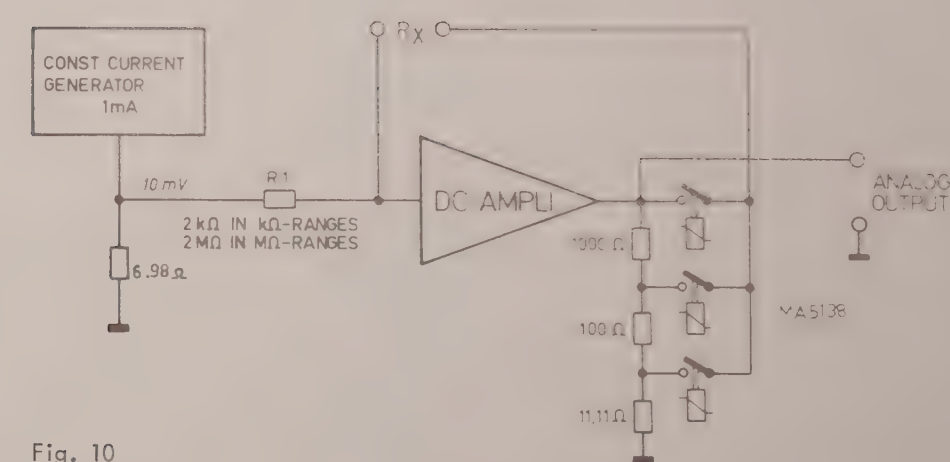


Fig. 10

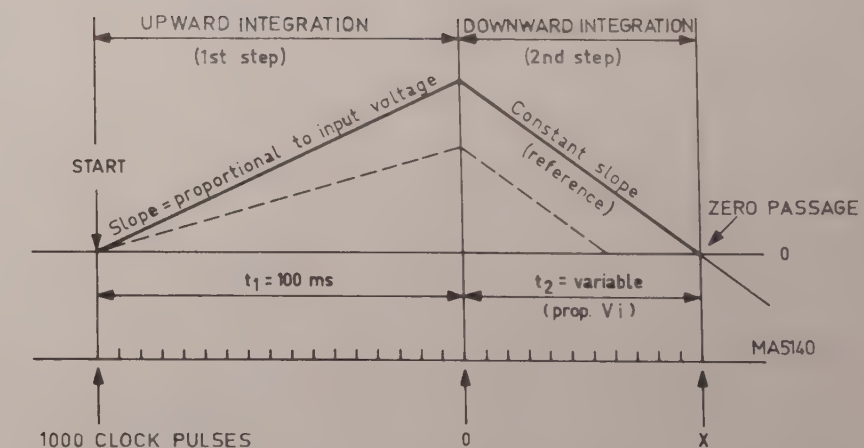


Fig. 11

V. Mise en place

MODE D'EMPLOI

V-1. Adaptation à la tension secteur locale

Avant la mise en service de l'appareil, il faut vérifier si la tension d'alimentation est convenablement adaptée à la valeur de la tension du secteur. La tension réglée en usine est indiquée sur l'adaptateur de tension (230 V ou 115 V) à l'arrière de l'appareil.
Des écarts de $\pm 15\%$ de ces valeurs sont admissibles; le fusible VL1 doit correspondre aux valeurs d'intensité suivantes:

Valeur nominale	Gamme de tension	Fusible VL1
230 V	200 ... 264 V	160 mA à action différée
115 V	100 ... 132 V	250 mA à action différée

Pour adapter l'appareil à un réseau 115 V il convient de dessouder deux petites connexions au transformateur secteur (comme indiqué sur la vue si contre). Pour ce faire le châssis doit être extrait du coffret de l'appareil par les deux poignées de verrouillage (voir VIII.1). Pour ouvrir le coffret, débloquer avec une clé intravis (BTR) les deux manettes servant de verrouillage le châssis dans le coffret et qui sont situées au dessous de boîtier, au droit de la plaque frontale.
Tirer vers l'extérieur en introduisant l'index dans le logement prévu à cet effet et sortir le châssis. Pour la fermeture du coffret, le châssis ayant été remise en place, repousser chacune des manettes et assurer leur blocage à l'aide de la même clé.
Attention: Ne pas raccorder l'appareil.
Les interconnexions doivent fre soudées de la façon indiquée fig. 13, page 65 pour la gamme de tension correspondente.
Après avoir soudé les connexions du transformateur pour une nouvelle valeur on placera l'indicateur réseau sur la tension correspondante.
Raccordement au secteur:
Le câble secteur à trois conducteurs est prévu pour le branchement sur une prise de sécurité à contact de "terre".

V-2. Mise à la terre

Lorsque l'appareil est branché aux secteur par l'intermédiaire du cordon secteur à trois conducteurs, le boîtier est connecté à la terre.
Si pour des motifs de sécurité, on désire une mise à la terre (par exemple lors de mesure de hautes tensions), l'appareil peut être mis à la terre par une conduite séparée à la borne de masse ($\equiv$) située à l'arrière de l'appareil (Fig. 14, page 65).
L'appareil contient un transformateur secteur spécial dont le primaire est blindé des deux côtés. Ces blindages sont raccordés au neutre du secteur, afin que les courants de fuite capacitifs du primaire passent à la terre par le blindage.
La tension d'admission maximale entre l'entrée de mesure "LO" et le boîtier est de 500 V CC.
Pour ce qui concerne la mise à la terre de l'instrument de mesure, se confirmer aux prescriptions de sécurité locales.

V-3. Composition

Le châssis de l'appareil du PM 2421 peut être monté dans un coffret universel à 6 modules (PM 9706) à la place du coffret universel à 4 modules. L'espace supplémentaire de ce coffret est prévu pour d'autres appareils du système modulaire 3E qui présentent un rapport avec le Multimètre Numérique ou qui peuvent même être utilisés indépendamment. Ce coffret universel à 6 modules a 19" le largeur et peut être monté dans un rack.
Si l'espace supplémentaire n'est pas utilisé, il peut être occupé par un tiroir.
Si l'on désire modifier la composition, on procédera comme suit:

- Retirer le capot plastique gris clair du boîtier PM 9706 et ôter les étriers cornières qui s'y trouvent.
- Retirer les 4 vis des 2 côtés.
- Soulever légèrement l'avant des panneaux latéraux et sortir les panneaux plastique qui sont dessous; les étriers cornières peuvent à présent être placés dans l'espace ainsi libéré
- Remonter les panneaux latéraux et visser avec les quatre vis
- Retirer les quatre pieds.
- Monter le nombre suffisant de rails de guidage contre les barres transversales supérieures et inférieures. Les trous dans les barres transversales sont filetés.
- Faire sortir le châssis PM 2421 du coffret universel à 4 modules et le faire coulisser dans un coffret à 6 modules.
- Remplir l'espace libre avec un bloc PM 9722 ou 2 blocs PM 9721
- Verrouiller les PM 2421 et PM 9722

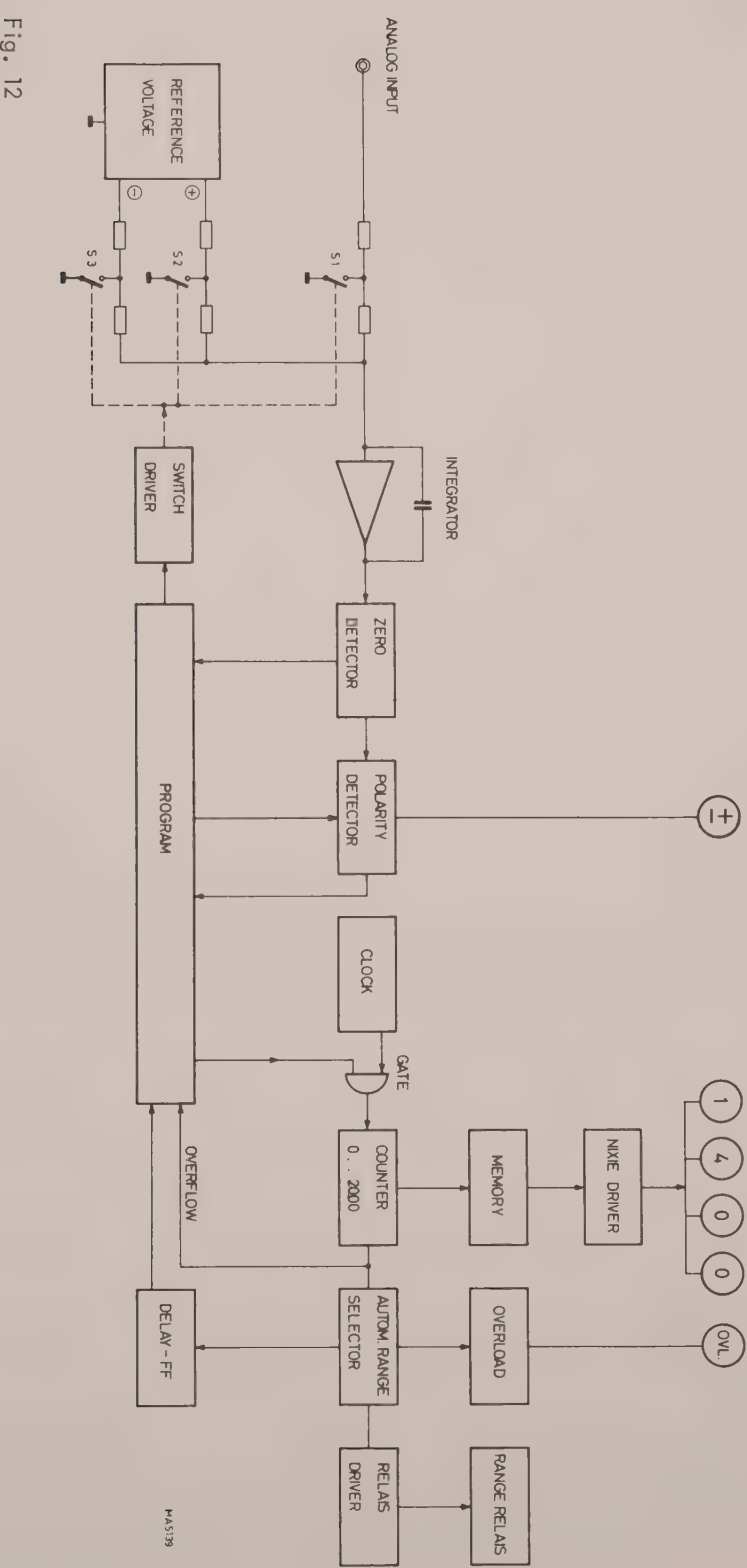


Fig. 13

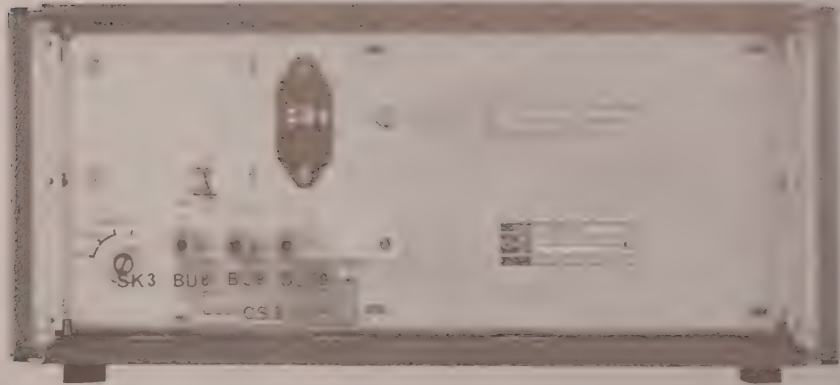


Fig. 14

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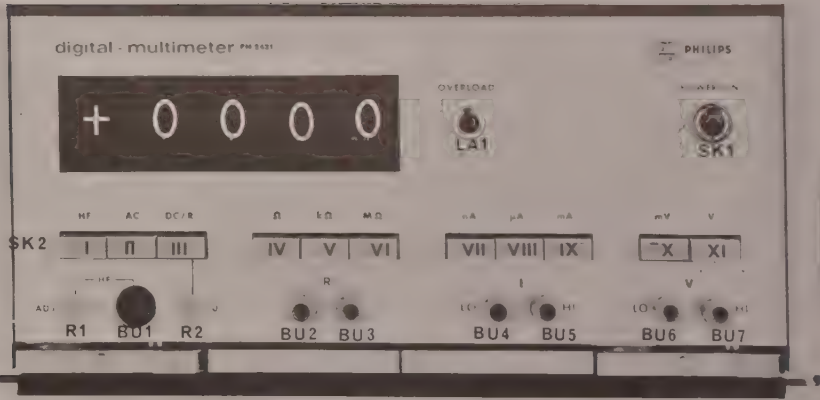


Fig. 15

VI. Mise en oeuvre

VI-1. Mise en circuit

Après connexion au secteur et mise à la terre selon les instructions, l'appareil est prêt au fonctionnement. L'appareil est mis en service par le commutateur "POWER ON"; les indicateurs d'affichage s'allument.

VI-2. Choix des mesures et connexion

La sélection des mesures s'effectue par boutons-poussoirs; on obtient en même temps le réglage approché par décades de 10^3 (1:1, 1:1000 ou 1:1000000). Pour la gamme sélectionnée et selon le résultat, une commutation dans le rapport de 1:1, 1:10 ou 1:100 a lieu automatiquement avec affichage comportant la virgule.

Les mesure "CC" et "R" (courant continu, tension continue et résistances) ont un poussoir commun, mais les douilles d'entrée sont séparées.

Le verrouillage des poussoirs exclut toute mauvaise manipulations du clavier sélecteur. La douille de gauche de la connexion "I" et "V" est lié au zéro du circuit et doit donc être utilisé comme "LO" (LOW = bas).

La mesure de tension HF (>1 MHz) s'effectue avec la sonde mesure spéciale VHF (et avec le Té hybride pour câble coaxial).

On connectera cette sonde à la douille "HF" à 5 pôles sur la plaque frontale.

VI-3. Affichage de la valeur et commutation des gammes de mesure

Le résultat de la mesure est affiché par indicateurs cathodiques. La virgule est également affichée automatiquement avec la gamme commutée.

Dans chaque plage de mesure (mV, V, nA, μ A, mA etc.), la commutation de la gamme de mesure se fait automatiquement, la commutation manuelle est également possible.

Fonctionnement automatique

Sur "automatique", le diviseur de tension à basse impédance reçoit les ordres de commutation en fonction de l'affichage. Si cet affichage se situe dans les gammes moins sensibles de 180 ou inférieures, il commute sur la gamme suivante; si l'affichage est voisin et supérieur à 1998 points la commutation s'effectue sur une gamme moins sensible. Cette commutation automatique reste jusqu'à ce que l'affichage soit situé entre 180 et 1998, ou que l'une des deux positions extrêmes de la gamme reste enclenchée. Lorsque, dans la gamme la moins sensible, l'affichage se situe vers 1998, ou au-delà, la lampe-témoin "OVERLOAD" s'allume étant donné que la limite de mesure garantie dans la gamme présélectionnée est atteint. Dans la gamme la plus sensible, même en-deça de 180 points, l'affichage reste stable.

Dans la gamme d'affichage entre 180 et 1998, la valeur lue peut être aussi maintenue si une précision plus grande est requirés entre 1800 et 1998. Cela se fait, lorsque la position moins sensible est enclenchée par surcharge ou oscillation de la valeur de mesure.

On peut mettre en service le dispositif automatique afin que la mesure débute dans la gamme la plus sensible et que l'affichage apparaisse entre 180 et 1800; pour des mesures de tension et de courant avec un bref enclenchement dans la gamme de mesure approchée la plus haute, et un bref court-circuit des douilles "R", provoque la commutation vers la gamme suivante pour les mesures de résistance.

Sélection manuelle

Dans le cas de mesures en séries dans une seule gamme, la commande manuelle est recommandée. Cette méthode procure un gain de temps (étant donné que la durée de commutation est annulée) et une sécurité de manipulation; la lecture rest homogène.

Le commutateur à commande manuelle se trouve à l'arrière de l'appareil et il doit être actionné par tournevis. Ce commutateur correspond aux quatre étages de commutation 1000, 100, 10 et "AUTO".

La commande automatique est désignée par "AUTO", les autres positions correspondent respectivement aux différents coefficient de mesure 10, 100 et 1000.

VI-4. Indication de polarité

La polarité est affichée automatiquement par un signe + ou - sur tubes cathodiques pour des mesures de tension ou de courant en continu. Cet affichage correspond à la douille "HI" (high = haut). L'indication s'éteint lors des mesures de résistances et le signe "~" apparaît lors des mesures en alternatif (fréquences industrielles et VHF avec la sonde).

VI-5. Mesure de tension CC

Enfonce la touche "DC/R" pour les mesures CC. La touche "mV" est valable jusqu'à 1,998 V au-delà on utilise la touche "V".

Avant d'enclencher une mesure de tension on vérifie si la gamme de mesure la plus sensible est bien enclenchée; le point décimal doit se situer à 00.00. Le bouton "0" sert au réglage du zéro; il doit être placé de telle façon que lorsque le circuit de mesure est ouvert, on ne puisse voir que des 0 partout. Il faut ensuite régler le point correspondant à l'inversion de polarité; pour cela, lors du passage de +/- . Après connexion de la tension à mesurer à les douilles "V", on lira la polarité et la valeur de mesure de cette tension.

Lors de mesure de tension très faibles (en-dessous de quelques mV), on peut désirer effectuer une mesure de la source de tension exempte de tensions thermiques. Il faut alors exécuter le réglage du zéro après avoir court-circuité les cordons de mesure juste à l'endroit de la source. Il est alors possible de compenser les tensions thermiques dans le circuit de mesure à l'aide du bouton 0. Après réglage et élimination du court-circuit on peut raccorder la source de tension à mesurer et effectuer la mesure correcte de cette source.

Mesures hautes tensions

Pour les mesures de tensions entre 1 kV et 30 kV on utilise une sonde haute tension PM 9246 cette sonde doit être raccordée aux douilles "V" tout en raccordant le pôle de mesure à "HI" et le pôle marqué de "⏏" à "LO" de la double prise.

La valeur affichée par le PM 2421 dans la gamme "V" est alors à multiplier par le facteur 100.

ATTENTION !!!

Toujours connecter d'abord le cordon de terre de la sonde au châssis ou au pôle "0" de la source de haute tension; après cela la haute tension peut être mesurée à l'aide de la sonde.

VI-6. Mesures de tension en alternatif

On sélectionne la mesure en enclenchant le poussoir "AC". Le réglage approche des gammes de tension se fait grâce aux touches mV et V; la touche "mV" jusqu'à 1,998 V et la touche "V" pour des tensions plus élevées jusqu'à max. 500 V.

Lors du raccordement de la tension à mesurer, il faut veiller à ce que le potentiel de mesure voisin à la masse soit connecté à la douille "LO". Afin d'éviter les erreurs de mesure, les cordons de mesures doivent être connectés de façon qu'il n'y ait pas de boucles de terre.

Les courants induits capacitifs, du fait du secteur, provoquent des chutes de tension dans les cordons de mesures et peuvent ainsi influencer la mesure.

La tension alternative appliquée peut être superposée à une composante continue jusqu'à 400 V.

VI-7. Mesures de courants

Les douilles "I" sont court-circuitées lors de mesures de tension et de résistances et sont branchées au zéro du circuit.

Enfoncer la touche "DC/R" pour la mesure de courant continu et la touche "AC" pour les courants alternatifs. Il faut aussi enfoncer les touches nA, μ A, ou mA selon le courant à mesurer. Lorsque l'ordre de grandeur du courant à mesurer est inconnu, il vaut mieux enclencher d'abord la gamme de mesure la plus élevée, c'est à dire la gamme "mA", car sinon les résistances shuntées pourraient être endommagées.

Le circuit de courant (surtout pour des mesures en alternatif) doit être connecté de manière à ce que le potentiel voisin à la masse du circuit de courant se trouve à la douille "LO".

Eviter la formation de boucles lors de mesures de courant alternatif!

La chute de tension est de 1 mV par nA, μ A ou mA selon la gamme de mesure prééglée. Devant cette proportion, on voit que la chute de tension dépend du chiffre affiché.

Lorsque la chute de tension est considérable pendant les mesures de courant, (lors de résistance de source peu élevée), la mesure doit être effectuée dans deux gammes différentes; une influence éventuelle de la différence de gamme est alors visible au résultat. A l'aide de shunts séparés, il est possible de maintenir la chute de tension minimale aux douilles "I" pour toutes les valeurs situées en-deçà de 19,98 mV.

Afin de protéger les résistances R6 et R10 contre la surcharge, le circuit de courant (sur les douilles I, BU4 et BU5) est protégé par un fusible de 1,6 A (VL3).

Ce fusible se trouve au dessous de l'appareil près de la douille BU5.

VI-8. Mesures de résistances

La mesure de résistances est enclenchée à l'aide de la touche "DC/R". La résistance à mesurer est raccordée aux douilles "R".

Les poussoirs " Ω ", "k Ω " ou "M Ω " permettent la sélection de la gamme approchée. La mesure s'effectue à l'aide d'un courant continu; cela permet de mesurer la résistance bobinées ou d'enroulements de transformateurs.

ATTENTION ! ! !

Etant donné que les circuits pour mesures de résistance ne sont pas protégés contre les tensions externes, on recommande la prudence. En cas de raccordement erroné à une tension externe supérieure à env. 5 V_{eff}, certains composants peuvent s'en trouver endommagés.

Procéder au réglage du zéro comme suit:

Gammes " Ω "

Court-circuiter les douilles R; régler l'affichage sur 0000 par le bouton "0". Si la résistance des cordons de mesure doit être éliminée, le court-circuit doit se faire à l'extrémité de ces cordons de mesure.

Gammes k Ω et M Ω

Le circuit de mesure est différent pour ces gammes de mesure (voir aussi point IV-2.4). Le réglage du zéro n'est plus essentiellement dépendant de la valeur de résistance, mais dépend de l'amplification. Il faut donc enfoncer la touche "V" pour le réglage du zéro. On règle à présent sur 0000 à l'aide du bouton "0". Lâcher la touche "V" et enfoncer la touche "k Ω " ou "M Ω ". On ne doit pas court-circuiter les douilles "R".

Pour les très petites valeurs de résistances, il faut tenir compte de ce que des tensions thermiques éventuelles peuvent fausser la valeur de mesure. Dans ces cas critiques, il est préférable de procéder au réglage du zéro comme décrit sous le point "gamme Ω ".

Le court-circuit se fera alors immédiatement à l'objet mesuré et non aux douilles.

Un courant de 1 mA parcourt la résistance inconnue dans les gammes Ω . De ce fait on peut sans inconvénient effectuer des mesures sur des semi-conducteurs selon la tension de diode et la courbe de température, pour un courant de passage de 1 mA.

Pour des résistances élevées (au-delà de 100 M Ω) la durée de la mesure est relativement longue étant donnée le courant de mesure faible. Dans ce cas, des ronflements peuvent fausser les mesures; il est alors conseillé de blinder les résistances à haute impédance, ce blindage devant être reccordé au zéro du circuit, par exemple à la douille "LO" de l'entrée "I".

VI-9. Mesures de tensions HF

La sonde PM 9203 et un atténuateur capacitif sert à la mesure en haute fréquence (≥ 1 MHz), le Té hymbride PM 9253 sert aux mesures sur des câbles coaxiaux jusqu'à 1200 MHz.

La gamme HF du PM 2421 est un détecteur HF très sensible du fait du système de réglage utilisé. Ceci n'est pas seulement valable pour le signal à mesurer, mais pour toutes les tensions d'interférence. Les signaux de quelques μ V peuvent être détectés et indiqués par le PM 2421. Les fortes intensités de champ d'interférence, telles qu'elles se présentent à proximité d'émetteurs de télévision et radio peuvent entraîner les interférences précitées! Il existe d'autres sources d'interférence, telles que des machines électriques, des moteurs thyristorisés, etc.

Le calibrage du PM 2421 pour mesures HF a été conçu pour de très petites tensions afin d'améliorer la caractéristique de diode du quadruplet de diodes présentes dans la sonde. Le calibrage avec bouton "ADJ. HF" peut être nécessaire lorsque des tensions inférieures à 10 mV sont à mesurer avec plus grande précision. La précision pour tension supérieures à 10 mV n'est pratiquement pas influencée par le calibrage.

Afin d'utiliser réellement la sensibilité du PM 2421, il est nécessaire d'effectuer des mesures sensibles dans une cage de Faraday. La calibrage peut également s'y faire exactement.

Les tensions d'interférence peuvent influencer la mesure de façon désavantageuse et ce comme suit:

- Par le réseau local ou le transformateur secteur
- En tant que tension entre la douille "LO" et le boîtier (ce dernier n'est pas conducteur HF idéal).
- Sur l'arrangement de mesure, lequel est influencé par une champ HF.

Il est impossible de diminuer les effets de la tension d'interférence sans faire de fortes dépenses. C'est pourquoi nous vous donnons les renseignements suivants:

- Pour bien utiliser la sensibilité de l'appareil, il faut effectuer les mesures dans un espace sans champ d'interférence (cage de Faraday). Le calibrage et la mesure ne présentent dès lors aucun problème.
- Le calibrage "HF-ADJ" n'est nécessaire pour les mesures ≤ 10 mV que lorsque la précision maximale est exigée.
- Le calibrage "HF-ADJ" ne peut exercer qu'une minime influence sur la précision des mesures supérieures à 10 mV. Pour les valeurs de tension supérieures l'appareil fonctionne à la précision voulue et sans calibrage.

On raccorde la sonde à la prise à 5 pôles sur l'avant et l'on enclenche la mesure à l'aide de la touche "HF".

Pour des mesures de tension inférieures à 10 mV ainsi que lors de variations importantes de la température de la sonde, il faut établir un étalonnage. A cet effet on utilisera le réglage "ADJ, à l'avant, ainsi que la douille "300 kHz OUT", à l'arrière.

Cette douille délivre une tension de comparaison pour l'étalonnage.

Réglage:

- Mettre l'appareil en service
- Enfoncer la touche "mV"
- Connecter la douille "300 kHz OUT", à l'arrière, par un fil à la douille "V" (HI)
- Connecter la sonde HF à la douille "300 kHz OUT" et le câblage de mise à la terre de la sonde à la douille "LO"
- Lire la valeur affichée (attendre env. 20 sec.)
- Enfoncer la touche "HF"
- A l'aide du potentiomètre "ADJ." régler le plus précisément possible sur la valeur précédemment lue.
- Placer l'index du bouton "ADJ." de telle façon que la flèche pointe vers le haut, en position de réglage fin.
- Détacher la sonde de la douille "V" (HI) et éloigner la connexion de la douille "300 kHz OUT".

L'étalonnage de la sonde ne doit pratiquement se faire qu'une seule fois, mais il faut cependant tenir compte que la flèche indicateur du bouton pointe verticalement vers le haut, puisque le potentiomètre se trouve en position de réglage fin (pour autant que la flèche soit montée convenablement).

Nota

Si la sonde mesure HF PM 9203 est connectée au PM 2421 et court-circuitée, une indication est encore toujours produite ($< 2 \text{ mV}$); en effet, pour des petites tensions d'entrée, il y a trop peu de signaux que pour fonctionner le système de régulation correctement.

Mesures

Des mesures de tension au-delà de 10 mV et jusqu'à des fréquences de 300 MHz, peuvent être exécutées sans précautions spéciales. Pour des faibles tensions d'entrée (inférieures à 5 mV), l'affichage ne se fait que lentement. On peut éliminer les parasites éventuels produits par exemple par des champs HF en court-circuitant les douilles "V" (HI et LO) et en raccordant simultanément les deux douilles R à "LO de "V".

Lors de toutes les mesures HF, il faut veiller à ce que le boîtier de la sonde, soit relié le mieux possible à la masse grâce au câble de mise à la terre.

Etablir la connexion la plus courte possible, blinder éventuellement le circuit (protection contre les parasites HF possibles des émetteurs). On conçoit l'utilisation du Té hybride pour la mesure de tensions à des fréquences élevées. Ce Té hybride peut être raccordé à l'aide du câble coaxial à connecteur BNC au circuit de mesure. La sonde HF est reliée au Té hybride en y vissant le conducteur HF. Un diviseur de tension capacitif est disponible pour la mesure de tension entre 1,998 V et 199,8 V, le rapport de division est de 100:1. Etant donné que ce diviseur se trouve devant les diodes de mesure, l'affichage de la virgule n'est plus exact. Pour cela on doit multiplier le résultat par 100 dans la gamme "mV".

VI-10. Sortie analogique

Dans l'entrée analogique, toutes les tensions de mesure sont converties en valeur de tension continue du même ordre de grandeur. L'importance de cette tension continue dans l'étendu d'une plage de mesure est continuellement proportionnelle à la valeur d'entrée et correspond à 3,5 mV pour 1 Digit; il en résulte que l'indication finale de 2000 digits présente une tension de sortie de 7 V. Une résistance de 5,6 k Ω est connectée en série à la source de tension analogique, afin d'éviter des réactions sur l'affichage lors du court-circuit de la sortie analogique.

La sortie du signal analogique se trouve à l'arrière, aux deux douilles de connexion "ANALOG OUT". Le PM 2421 permet ainsi l'utilisation comme amplificateur de tension continue ou transformateur AC-DC, ainsi que pour la commande d'enregistreurs.

VII. Circuit description

SERVICE DATA

VII-1. CHOPPER-STABILISED D.C. AMPLIFIER (U1) Fig. 19.

VII-1.1. General

The chopper-stabilized d.c. amplifier is used for direct voltage, direct current and resistance measurements.

For H.F. measurements the amplifier is included in a control circuit. Without negative feedback the d.c. amplifier has such a high d.c. gain that even without input signal (thermal voltages) it will give a maximum output. The working principle of this d.c. feedback amplifier is clarified with the aid of the simplified diagram in Fig. 16.

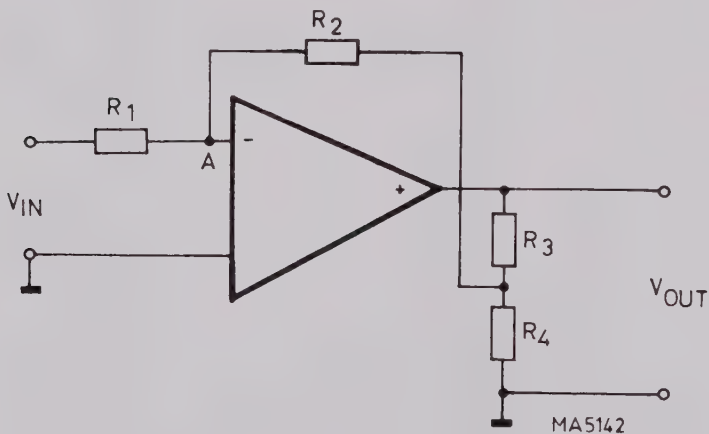


Fig. 16 D.C. amplifier

At all the ranges of the PM 2421 a digital reading of 1000 will be obtained when the output voltage V_{out} is 3.5 V.

If it is assumed that the internal gain is $5 \cdot 10^7$, the voltage on summing function A will then be $\frac{3.5 \text{ V}}{5 \cdot 10^7} = 0.07 \text{ } \mu\text{V}$.

In the most unfavourable case (at maximum gain), the corresponding input voltage will then be $V_{in} = 10 \text{ mV}$. As the voltage drop is negligibly small compared with the input signal (max. 0.01% of V_{in}), it follows from the above diagram that:

$$-\frac{V_{in}}{R_1} = V_{out} \frac{R_4}{R_2(R_3 + R_4)} \text{ or } -\frac{V_{out}}{V_{in}} = \frac{R_2}{R_1} \left(\frac{R_3}{R_4} + 1 \right)$$

The minus sign shows that the amplifier operates as an inverter, i.e. it supplies a negative output voltage when the input signal is positive. In the case of direct voltage, direct current and resistance measurements (Ω ranges only) the value of $R_1 = 1 \text{ M}\Omega$ and that of $R_2 = 3.5 \text{ M}\Omega$. At the most sensitive range, the ratio R_3/R_4 is 99/1, so that the voltage gain will be 350. At the middle range $R_3/R_4 = 9$, and the gain is 35. At the least sensitive range R_3 will be 0 and the voltage gain 3.5. In the case of $\text{k}\Omega$ and $\text{M}\Omega$ measurements V_{in} and R_1 are constant; the unknown resistance is represented by R_2 . The output voltage at various resistance values can be calculated if it is known that $V_{in} = 6.98 \text{ mV}$, and that the value of R_1 is $2 \text{ k}\Omega$ at the $\text{k}\Omega$ ranges and $2 \text{ M}\Omega$ at the $\text{M}\Omega$ ranges.

VII-1.2. Block-diagram chopper-stabilized d.c. amplifier (Fig. 17)

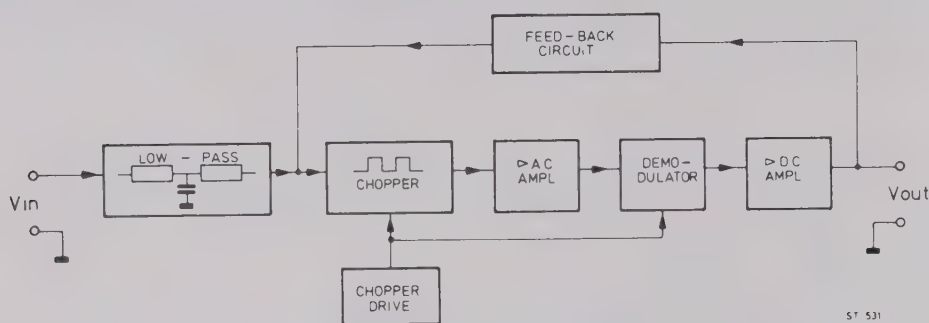


Fig. 17 Block-diagram d.c. amplifier

The a.c. component of the d.c. input signal is suppressed by the low-pass filter. The filtered d.c. signal is converted into a square-wave signal by the photo chopper and amplified by the a.c. amplifier. After this amplification of $10^4 \times$ the measuring signal is big enough to demodulate and to amplify it by the d.c. amplifier. The feedback circuit reduces the total d.c. amplifier gain to a desired value in the used measuring range.

VII-1.3. Chopper, auxiliary amplifier and demodulator (Fig. 19)

The a.c. component of the input signal is suppressed by the low-pass filter formed by R_{101} , 102 , 103 , 104 , 105 , R_{106} and C_{101} , 102 and C_{103} . The total resistance of R_{101} , 102 , 103 , 104 , 105 and 106 is about $1 \text{ M}\Omega$. When the feed-back circuit is formed by R_{149} ($3\text{M}\Omega$), the total amplification must be $3.5 \times$.

This can be adjusted by R_{101} (course) and R_{102} (fine). In this case the output attenuation of the total d.c. amplifier must be $1 \times$. Neon lamp LA_{101} serves as overload protection of the input of the total amplifier. With potentiometer R_{109} , the offset current can be corrected. The d.c. signal at point 3 is converted into a square wave by the photo-chopper. This square-wave voltage is lead to the a.c. amplifier. TS_{101} and TS_{102} form a high-to-low resistance transformer to get a low noise voltage at the input of the a.c. amplifier I.C. $101.a$. The a.c. amplifier is fed-back by resistor R_{115} . With the feedback resistor R_{115} and R_{150} the a.c. amplification of this amplifier is $10^4 \times$. The d.c. component is blocked by capacitor C_{106} . So the amplification of the d.c. signal is $1 \times$, as result of coupling the output to the input by R_{115} and isolating the input from the ground by C_{106} .

Diodes GR105 and GR106 limit the output voltage of the a.c. amplifier I.C.101.a. Potentiometer R102 serves for voltage offset correction. Capacitor C108 and resistance R118 serve to prevent H.F. oscillations of the amplifier I.C.101.a. TS103 forms the demodulator and is driven by the same a-stable multivibrator as the chopper. By this the demodulator is synchronised with the photo-chopper. When the serie-resistance of the photo-chopper is low-ohmic, the M.O.S. - F.E.T. TS103 will than be low-ohmic too.

The demodulated signal is amplified by the d.c. amplifier I.C.101.b.

The output signal is via the output power stage (emitter-follower) and capacitor C110 coupled to the input of the d.c. amplifier I.C.101.b. This is done to correct the pulsed d.c. voltage, made by the demodulator. So amplifier I.C.101.b. has also an integration function. The chopper drive circuit supplies the voltages required for driving the photo-chopper and the demodulator. The a-stable multivibrator formed by transistors TS109 and TS110 has a frequency of about 1.8 kHz. The pulse is sharpened with diodes GR111 and GR112.

Transistors TS108 and TS111 serve for the current drive of the L.E.D.'s in their collector.

TS112 drives demodulator TS103.

VII-2. AC-TO-DC CONVERTER (U2), Fig. 21

The high-ohmic voltage divider comprising resistors R201 ... R204 and capacitors C201 ... C203 is used at the V-ranges for direct and alternating voltage measurements. Its division ratio is 1000:1. This ratio can be adjusted with potentiometer R204 for direct voltages and alternating voltages with low frequencies. Frequency-independent voltage division is ensured by the capacitively adjusted divider (adjustment has also been effected for the varying stray capacitance of the circuit elements).

The impedance matching stage comprises field-effect transistor TS201 and transistors TS202 and TS203. TS201 and TS203 operate as a voltage amplifier; TS202 is an emitter follower. The high internal voltage gain is reduced to unity by negative feedback. The series-parallel feedback applied stabilises the voltage amplification and reduces the output impedance. Capacitor C204 at the input serves for blocking d.c. components superimposed on the alternating voltage to be measured. Resistor R208 and diodes GR201/GR202, which are reverse biased, protect the field-effect transistor against excessive input voltages. For direct voltages the gate of TS201 is connected to the circuit zero via R207. Consequently, the direct voltage on the collector of TS203 will correspond to the gate-source voltage of TS201 between +0.5 V and +3.5 V with respect to the circuit zero.

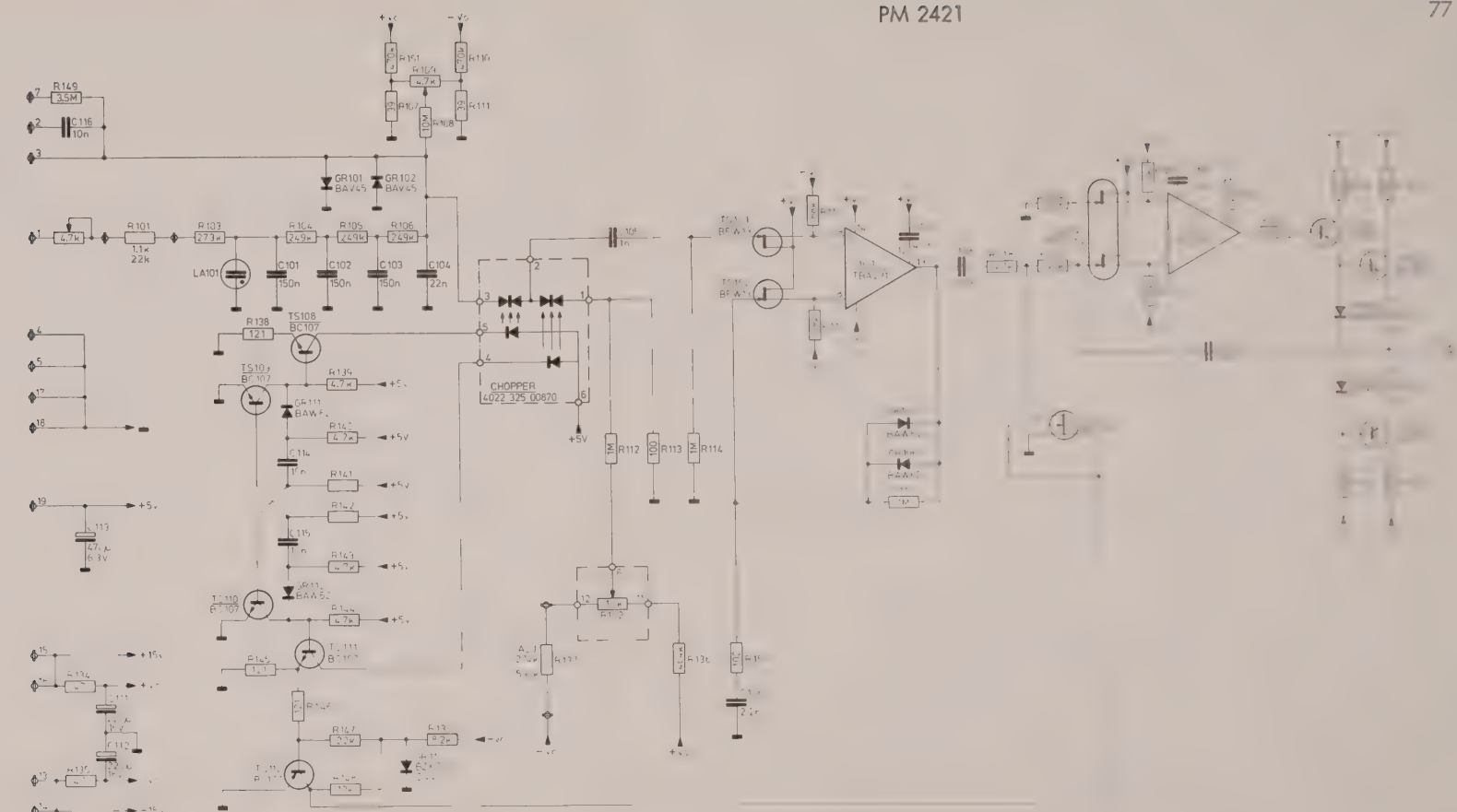
In the case of AC and HF operation the impedance matching stage is connected to the low-ohmic voltage divider via capacitor C207. The output voltage of this divider is applied to the input of the voltage amplifier via resistor R217.

The voltage amplifier consisting of transistors TS204, TS205 and TS206 has a high internal gain (more than 300). In the fed-back condition its voltage gain, dependent on the value of R229 and R224, is approx. 17 for alternating voltages up to more than 1 MHz. The feedback network includes several correction elements (C209, R223; C211; C210, R229; R228, C212), which permit of adjusting the desired frequency response.

With the aid of resistor R225 the gain is adjusted within limits of $\pm 0.3\%$. The entire circuitry following the low-ohmic voltage divider is d.c. coupled to the analogue output. This circuit arrangement enables short recovery times at a good LF frequency response.

Diodes GR203 and GR204 limit the input voltage in case of overloads. R228 serves for adjusting the working points of transistors TS207, TS208 and TS209. The direct voltage on the base of TS210 should be approx. -3.5 V. Stabilisation of the d.c. setting is effected with the aid of TS210.

The amplifier with transistors TS207, TS208 and TS209 has a very high no-load voltage gain. The rectifying diodes are included in the feedback circuit. In the absence of an input voltage there is no negative feedback; the internal gain is then very high. Even when the input voltage is increased slightly, the diodes will become more conductive.



The larger the current through the diodes, the more the feedback voltage increases; the voltage gain is then reduced. The rectifying network ensures that the current is proportional to the input voltage. This current causes a voltage drop across R241 and R242 whose value corresponds to the average value of the alternating input voltage. The slope (output direct current versus input alternating voltage) of the amplifier-rectifier circuit is in the first instance determined by R233 and R239.

The voltage across GR209 causes an apparent reduction of the knee voltages of GR208 and GR210. Network GR211/R244 slightly improves the linearity. R242 permits adjustment of the output voltage (accuracy better than 0.03%).

The direct voltage obtained across R241/R242 after rectification is symmetrical with respect to the circuit zero. It comprises a d.c. component and an a.c. component. The low-pass filters consist of R243 ... R247, C220/C221; they serve to smooth the rectified mains voltage. One section of the differential amplifier, with TS213, TS212 and TS211, and the other section, with TS213, TS214 and TS215, each form an impedance matching stage. The offset voltages and currents of these impedance matching stages and of IC201 are compensated for by means of R249. On the outputs of the impedance matching stages, two superimposed direct voltages arise. On direct voltage is determined by the setting of TS209 and is the same for both sections of TS213. The other voltage is the difference between the direct voltages; it depends on the value of the input signal and provides asymmetrical drive for TS213. The following differential amplifier including IC201 and feedback resistors R255 ... R261 has a high common-mode rejection, which is accurately adjustable with the aid of R259. The gain for the difference signals is about ten. Thus, on the output of IC201 a direct voltage is obtained with respect to the circuit zero, whose value corresponds to the alternating voltage on the input and which contains practically no a.c. components.

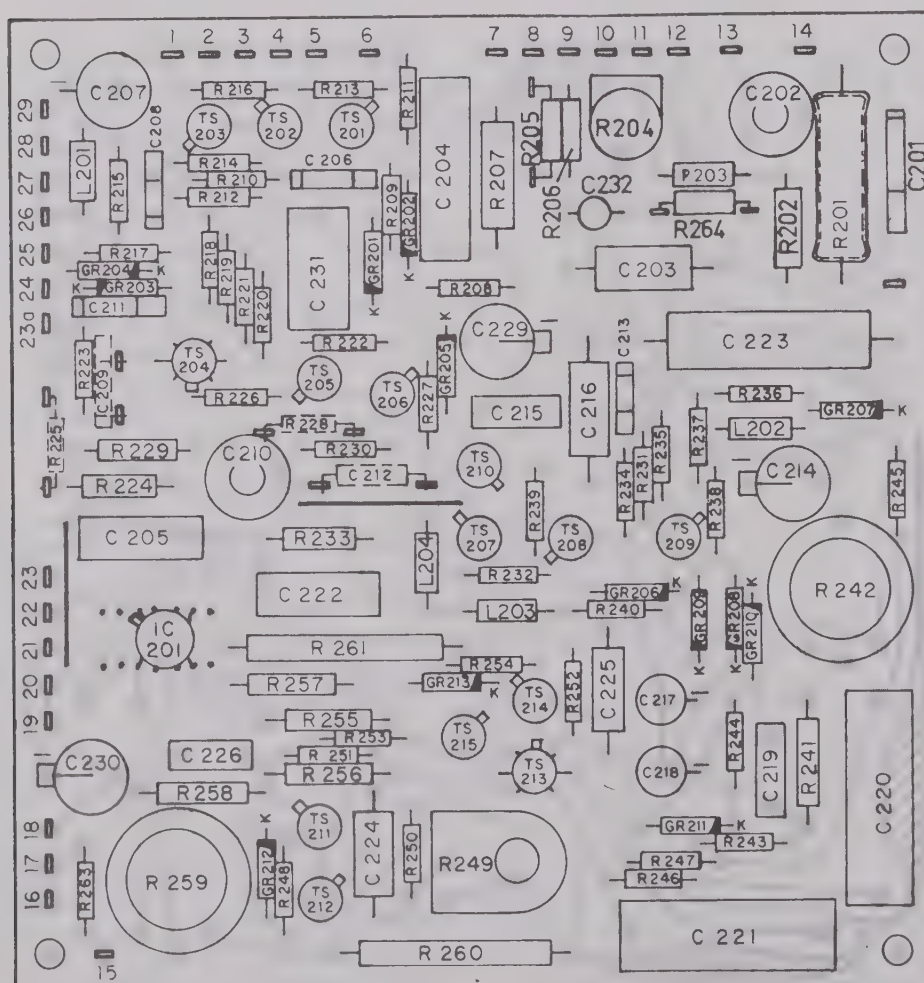


Fig. 20 Printed circuit board U2

MA5160A

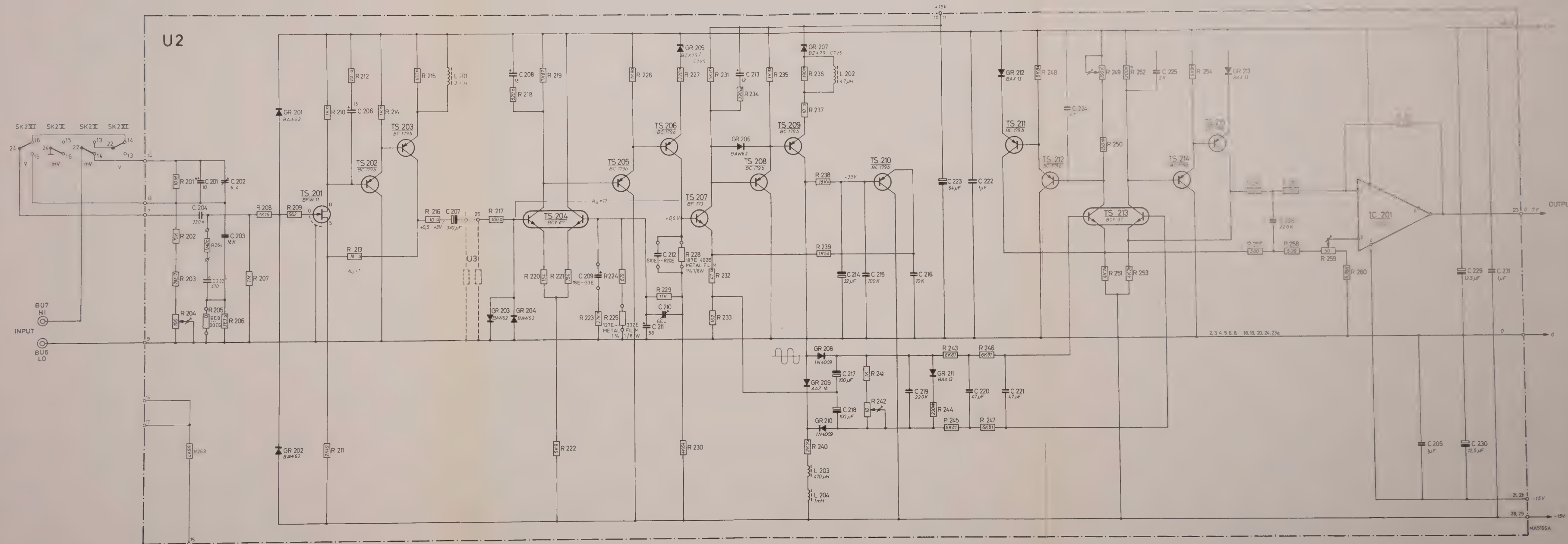


Fig. 21 Circuit diagram of the a.c. - to - d.c. converter



VII-3. 300 kHz OSCILLATOR, CONTROL CIRCUIT, DC CURRENT GENERATOR AND AUTOMATIC CONTROLLED VOLTAGE DIVIDER (U3) Fig. 23

VII-3.1.300 kHz Oscillator

Transistor TS301 which is connected as an emitter follower operates as an oscillator. The voltage gain of an emitter follower lies slightly below unity. By means of the coil of the resonant circuit it is achieved, that the product of gain factor and feedback is slightly higher than one. The amplitude of the oscillator is determined by the coil, the current through TS301 and the limiter in the base-emitter circuit of TS301. The current supplied by TS301 is controlled by TS302. The output voltage of the d.c. amplifier is applied to point 27. When this voltage is almost equal to zero potential, TS302 is cut off. When the input d.c. voltage is increased by $-0.5 \dots -0.7$ V transistor TS302 will become more conductive, so that the oscillator voltage increases. Due to the oscillator output voltage, a current arises through R310 to the inputs of the regulator stages, i.e. to the emitters of TS303 and TS304. The distribution of the current among TS303 and TS304 is controlled by the direct voltage supplied by the d.c. amplifier.

When this voltage is approximately equal to zero potential, the current will flow through TS303; TS304 is then cut off. The voltage drop across R314 is almost zero. When the d.c. input voltage is increased towards -0.7 V transistor TS303 becomes less conductive, so that the current through TS304 will increase accordingly. This direct current is superimposed on the 300 kHz voltage from the oscillator. Across R314 a voltage drop arises which is proportional to the current through TS304. As a result an alternating voltage of $0 \dots 1.7\text{ V}_{\text{rms}}$ will arise on the collector of TS304, whose value depends on the value of the d.c. input voltage across R307 and R309 (between 0 and 0.7 V). Capacitor C310 serves for blocking the direct voltage and TS305 effects impedance matching.

Via voltage divider R304, R305 a calibration voltage of approx. 1.7 mV is obtained.

The regulator also includes adjusting networks which ensure the accuracy of the H.F. voltage measurements. At higher voltages the working points of the diodes in the probe can be made symmetrical by means of potentiometer R337. Adjustment of the working point is effected with R331 (coarse) and R1 "ADJ." (fine).

VII-3.2. Direct current source (U3)

For resistance measurements a current source supplies a direct current of 1 mA at a very high output resistance.

The constant current is supplied by transistors TS307 and TS308 (the current through TS307 is very small with respect to the current through TS308). With the aid of voltage divider R321, R322 and R323 transistor TS306 is biased so that a current of 1 mA is obtained into R328.

Transistor TS306 compares the voltage across R328 with the voltage across $R322 + R323$.

The right-hand section of TS306, together with TS307 and TS308, forms a control circuit which stabilises the voltage across R328 at the preset value across $R322 + R323$. During normal operation TS309 is cut off; in the case of output voltages above 2 V it functions as a limiter.

VII-3.3. Automatically controlled voltage divider (U3)

The signals for changing over the voltage divider are obtained from the digital section. A detailed description of automatic control system is given in chapter VII-4.13.

In the case of AC and HF measurements the voltage divider is included in the AC- to DC converter between connection points U2/1 and U2/25. In the case of DC and R measurements, the voltage divider is included in the feedback circuit of the d.c. amplifier.

On printed circuit unit U3 three reed relays RE301 ... RE303 are mounted, which switch over the voltage divider consisting of precision resistors R340 ... R343. This voltage divider has a division ratio of $1:1$, $1:10$ or $1:100$, dependent on the positions of relays RE301 ... RE303.

Fine adjustment for the $1:100$ division is effected with R340. The diodes GR301 ... GR303 serve to short-circuit the induction voltage arising when the relay coils are switched out of circuit. GR304 ... GR306 prevent undesired ignition of the decimal point indication via the relay coils.

VII-4. DIGITAL SECTION (U4) Fig. 39

VII-4.1. Working principle

The working principle is explained with the aid of the logic circuit diagram, Fig. 39 and pulse sequence diagram, Fig. 24.

The measuring cycle is started when:

1. the programme flip-flops IC415 (A-FF) and IC416 (B-FF) are in the zero position ($Q_A = 0, Q_B = 0$).
2. Inputs J2 (4) and J3 (5) of flip-flop A (IC415) are in the "1" state.

Starting, however, is not effected until the negative edge of the next clock pulse appears (sequence diagram, programme flip-flop A). Output Q_A will assume the "1" state. Nand-gate IC414/A supplies control signal T2 for the integrator.

Inputs 1 and 2 are "1", so that the output 3 is "0"; the upward integration is initiated.

Simultaneously gate IC414/B at the input of the counter is opened (Input 4 is in the "1" state).

From the clock-pulse generator the clock pulses are now applied to the counter input (IC407/14) via IC414/B and IC414/D.

The counter is reset to 1000 by the preceding reset pulse, and because the counter gate is opened, it counts further to 2000, thus determining the duration of the upward integration period (100 msec.).

During counter position 1998, i.e. shortly before the end of the upward integration period, Nand-gate IC412 and IC417/C at the output of the counter supplies a pulse. The negative edge of this pulse triggers the polarity flip-flop (IC416/A, input 5). Thus the polarity of the integrator charge is stored.

At the same time, programme flip-flop IC416/B is switched over, so that output Q_B becomes 1, thus initiating the downward integration. Gate IC414/B remains open; the counter is set from 1999 to 0 and starts counting down the clock pulses, while the integrator is discharged with a constant current.

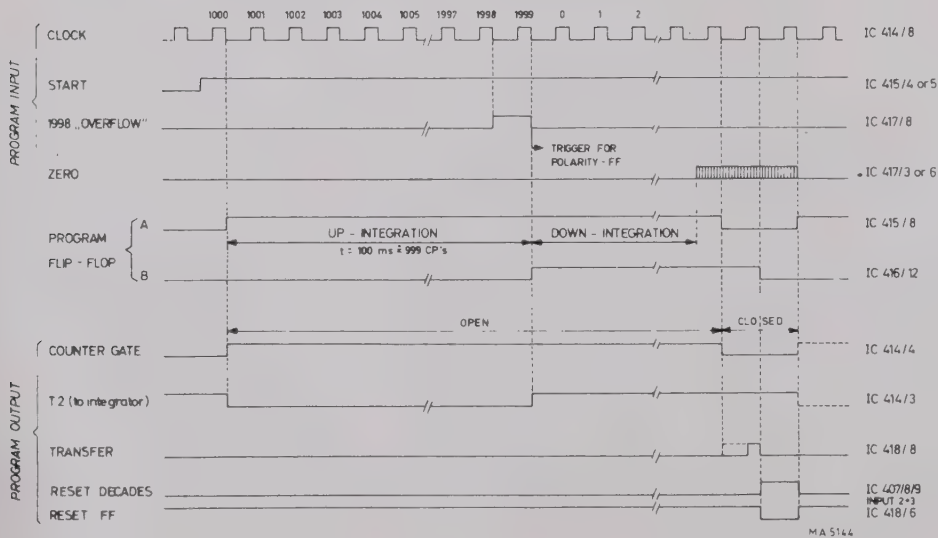


Fig. 24 Sequence diagram

When the integrator is discharged to zero, gate IC417/A or IC417/B supplies a "Zero" signal to the programme input (IC415 inputs 9 and 10). Upon the next negative edge of the clock pulse the programme is advanced one step. Gate IC414/B is closed (Q_A becomes 0), so that no more clock pulses can be applied to the counter. During the 1-condition of the next clock pulse the transfer pulse arises. As a result, the measuring result is transferred from the counter into the memory and is displayed by the indicator tubes via the BCD-to-decimal decodes/drivers IC401 and IC403.

The next clock pulse switches the programme to reset. Via the reset lines R1 and R2 the counter is then reset to 1000. Thus the circuit is ready for the following measuring cycle, which will be initiated by the next clock pulse if no stop signals are applied to J2 or J3 of IC415.

VII-4.2. Input circuit

After processing in the relevant input stages, the various measurements yield d.c. signals which should be converted into digital form by the digital section. The first step in this process takes place in the input circuit with the integrator. This is in fact the main function of this instrument, because here the analogue measuring signal is converted into digital form. Moreover, this function is decisive of the measuring accuracy. Analogue-to-digital conversion is effected in the integrator, which operates as follows:

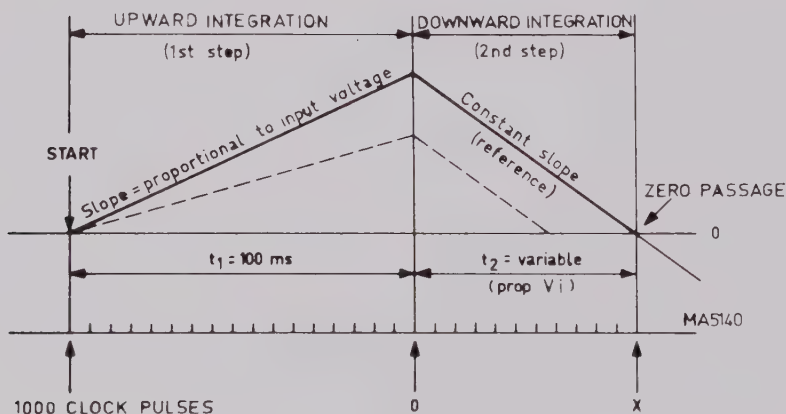


Fig. 25 Integration process

In the feedback circuit of operational amplifier IC424 integration capacitor C402 has been included (Fig. 26).

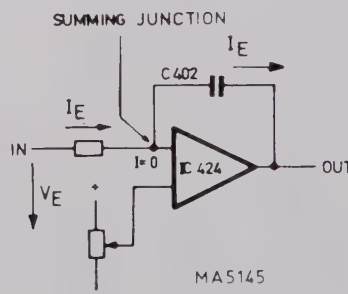


Fig. 26 Integration circuit

A current proportional to the input voltage to be measured U_E flows to the summing junction of the operational amplifier and into integration capacitor C402. At the end of the charging time (100 msec) the operational amplifier will supply an output voltage which is proportional to the unknown input voltage U_E .
The charging cycle (first step) is followed by the discharging cycle (second step), see Fig. 25.

Capacitor C402 is discharged with a constant current, determined by the positive or the negative reference voltage. The time required for a complete discharge (zero passage) is proportional to the input voltage. This time is measured by counting clock pulses and is processed for display (also see under IV-2.5. Description of the block diagram).

To the summing junction of the integrator (IC424 point 2) three different signals may be applied via shunt switches TS401 ... TS403.

During the first step TS401 is cut off (this corresponds to an open contact). Simultaneously, TS402 and TS403 are conductive. The input voltage (input 9) causes a current through R409 and R412 to the summing junction of the integrator (IC424 point 2).

As the summing junction is almost at zero potential, no current will flow into R413 and R414, although these resistors are connected to earth via TS402 and TS403. Moreover, there will be practically no current into the operational amplifier, because its input is very high-ohmic. Consequently, the current to the summing junction will flow directly to integration capacitor C402 which is then charged. As a result, a voltage will arise at the integrator output, which increases linearly with time.

During the second step TS401 is conductive because a base current of 2 mA is applied. TS402 or TS403 is cut off. As a result, the discharge current from the integrator is applied to the summing junction, i.e. the integrator output voltage changes to zero. The discharge current is determined by the reference voltage and resistors R401, R402, R403, R407, R410, R413 or R404, R405, R406, R408, R411 and R414.

For the operational amplifier a supply voltage of +15 V and -15 V is required. This voltage is applied to IC424 via smoothing filters R445/C411 and R447 + R448/C414, RC-circuit R423/C404 and C403 serves for phase correction. This is necessary to prevent oscillation of the amplifier which has a high degree of feedback.

Resistor network R415 ... R422 and R424 serve to compensate for the offset voltage. Coarse adjustment is effected with R424 and fine adjustment with R418.

VII-4.3. Comparator

Via R427 the output signal of the integrator is applied to the comparator which has a gain of 1000 ... 2000. At the end of the first step the comparator determines whether the polarity of the integrator output is positive or negative. Via a Schmitt trigger and switch drivers TS406 or TS407 it moreover selects the reference voltage for discharging the integration capacitor via TS402 or TS403. The offset voltage of the comparator does not affect the measuring accuracy.

The +12 V and -6 V supply voltages are derived from the +/- 15 V voltage by means of zener diodes GR406 and GR407.

VII-4.4. Schmitt trigger

To drive the IC logic, very steep pulses are required. These pulses are obtained by means of a Schmitt trigger consisting of TS404 and IC423/D.

Working:

At an input voltage V_E of 0 V transistor TS404 is cut off; its collector voltage is then approx. + 5 V (Fig. 27a). For input 12 of IC423/D, this represents a "1". This means that the output of IC423/D (output 11) is "0".

When the input voltage increases, TS404 is turned on at approx. + 0.7 V and the input (12) of IC423/D then receives a "0".

The output (11) will then be "1". Via feedback resistor R430 the transistor is then further bottomed (positive feedback).

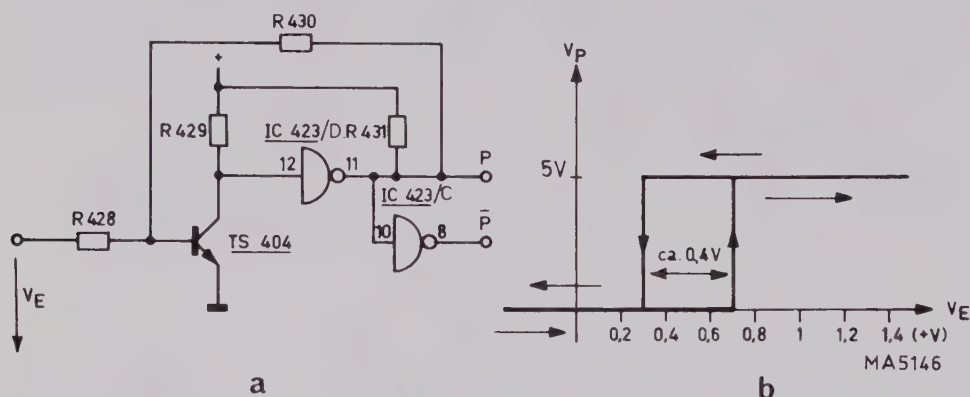


Fig. 27 Schmitt trigger

To reset the Schmitt trigger logically to zero, the input voltage should be reduced to approx. + 0.3 V. At this point the reverse process starts, i.e. TS404 is turned off.

Again rapid switching is ensured by means of positive feedback (the rise time is approx. 20 nsecs.). IC423/C supplies a signal $\bar{P}$, which is complementary to P. The P and $\bar{P}$ signals are used as control signals for the polarity flip-flop, the programme circuit, and switch drivers TS406 and TS407.

VII-4.5. Switch drivers

Switch drivers TS405 ... TS407 supply the control currents for switching transistors TS401...TS403. The switch driver transistors are controlled by the logic potentials, determined by the "T", P and $\bar{P}$ signals, on the cathodes of diodes GR403 ... GR405.

VII-4.5.1. The following criteria are a measure of the drive of TS401:

a. Input T2 logic 0 (approx. 0 V; Fig. 28a).

Via GR403 the current supplied by R432 is drained to the circuit zero. As a result

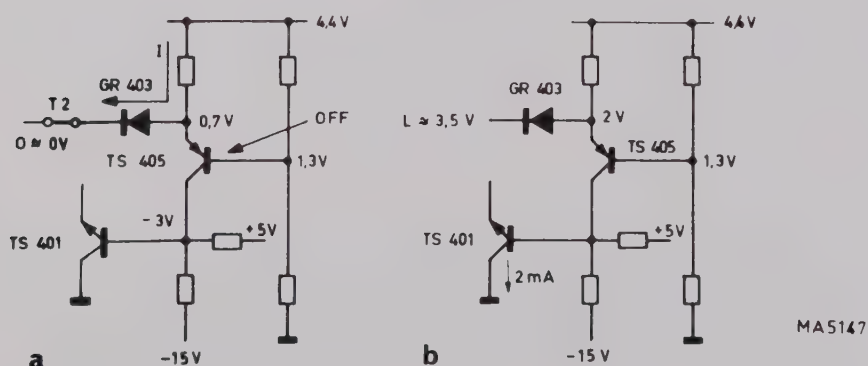


Fig. 28 Switch drivers

TS405 is cut off, and its collector potential becomes -3 V (determined by R436/R437). In that case switching transistor TS401 is cut off.

- b. Input T2 logic 1 (approx. 3.5 V ; Fig. 28b).

Diode GR403 is cut off, TS405 becomes conductive. The emitter current is distributed among R436, R437 and the base of TS401. The base current of TS401 is approx. 2 mA so that transistor TS401 is now conductive.

VII-4.5.2. The criteria for driving TS402 or TS403 are determined by Nand-gates IC423/A or IC423/B. Within these criteria there are two possibilities:

- a. During charging $T2 = 0$. Pulse $J (= P)$ from the Schmitt trigger may be "0" or "1".

However, during charging the output of gate IC423/A is always "1" so that GR404 is cut off.

As a result TS402 and TS403 will be conductive during charging.

- b. During discharging $T2 = "1"$.

Depending on the polarity, output P or $\bar{P}$ will be "1". The output of the gate of which both inputs are "1" will be "0" and the corresponding diode will be conductive.

Consequently TS402 or TS403 will be cut off.

VII-4.6. Working of transistor switch TS401 ... TS403

These transistors operate as shunt switches for the three inputs of the integrator. They are inversely connected, in order to obtain favourable properties as regards leak resistance and offset voltage (in the case of inverse operation the collector and the emitter function have been interchanged, i.e. driving is effected at the base-collector junction). Transistors TS401 ... TS403 have been selected as regards leak resistance, offset voltage and leakage current.

VII-4.7. Zero passage

Via the comparator and the Schmitt trigger the zero transient is applied to the programme flip-flops as a stop signal. The programme circuit then closes the gate at the counter input and the other programme steps are initiated. T2 remains "1" for the rest of the programme. After the zero transient the integrator automatically remains at zero. This is effected by alternately connecting the positive and the negative reference voltage to summing junction IC424/2.

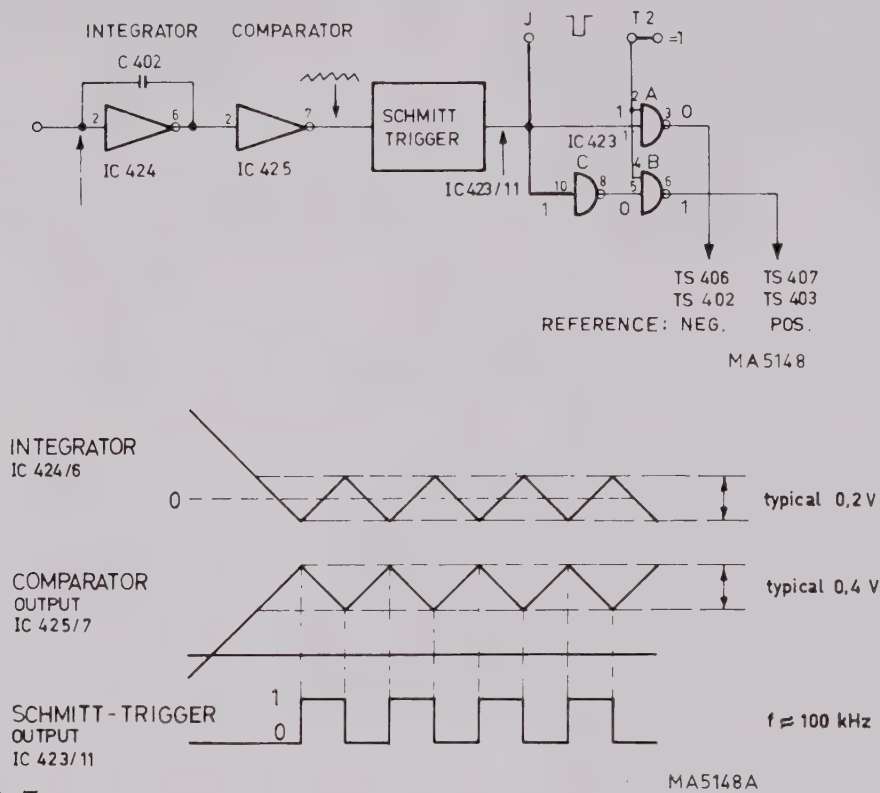
The control process is as follows:

Assume that the output voltage of the integrator changes from a positive potential to zero (Fig. 29). On the output of the comparator a positive-going voltage arises, which at approx. $+0.7\text{ V}$ sets the Schmitt trigger to the "1" state. Via gate IC423/A, TS406 and TS402 the negative reference will now control the integrator output in the positive direction. The voltage on the comparator output goes negative, passes through the hysteresis of the Schmitt trigger and sets the latter to 0 at approx. 0.3 V . As a result, the positive reference voltage will be applied etc. The accuracy of this process is approx. 0.2 mV , which corresponds to less than $1/10$ digit, so that it will not affect the measuring accuracy.

VII-4.8. Polarity flip-flop

The polarity signals P and $\bar{P}$ from the integrator are applied to set inputs J and K of polarity flip-flop IC416/A. When the 1998th pulse arrives (via gate IC417/C) at the clock input (5), the flip-flop is set for the duration of one clock pulse. The flip-flop then takes over and stores the polarity of the integrator charge and controls transistors TS410 and TS411, via gates

GR410/GR411 and GR412/GR413. Transistors TS410 and TS411, which control the anodes of the polarity indicator B405, are only turned on in the case of direct voltage or direct current measurements (SK2/III).



VII-4.9. Programme circuit

The programme circuit consists of flip-flop FF-A (IC415) and FF-B (IC416/B). The programme steps are controlled via inputs J_A , K_A and J_B and are synchronously with the clock generator. By means of gate circuits IC418/A and IC414/A the Reset, Up, Down and Transfer pulses are derived from the output signals Q_A , Q_A , Q_B and Q_B . These programme steps are represented in the table, Fig. 30.

		A_n	B_n	A_{n+1}	B_{n+1}	$J_A = \text{Start}$	$K_A = \text{Zero}$	$J_B = \text{Overflow}$	K_B	
Carry out Programme step	RESET	0	0	1	0	1	X	0	X	1
	UP	1	0	1	1	X	0	1	X	2
	DOWN	1	1	0	1	X	1	X	0	3
	TRANSFER	0	1	0	0	0	X	X	1	4
Carry out no programme step	RESET	0	0	0	0	0	X	0	X	5
	UP	1	0	1	0	X	0	0	X	6
	DOWN	1	1	1	1	X	0	X	0	7
	TRANSFER	0	1	0	1	0	X	X	0	8

Fig. 30 Table representing the programme steps

TRANSFER: $Q_A = 0, Q_B = 1$.

The duration of the transfer is only 50 μ secs. The output signal "1" of flip-flop A is present on input K of flip-flop B, i.e. flip-flop B is prepared to change over to $Q_B = 0$ on the negative edge of the next clock pulse (4th line).

RESET: $Q_A = 0, Q_B = 0$.

A 0-signal on input J2 or J3 of flip-flop A will stop the programme for an arbitrary time (5th line). If no external stop signal is given and the delay circuit is not released the duration of the reset period will be only one clock pulse.

Upon the next clock pulse, Q_A will become "1" (2nd line). Thus the following measuring cycle is initiated.

Overflow

This signal is derived from the counter by means of IC412, 417/D and 417/C. Only for counter position 1998 all the inputs of IC412 are in the "1" state. This state is used to control the programme circuit and to trigger the polarity flip-flop.

VII-4.10. Counter

The counter consists of three integrated counting decades IC407 ... 409 for the units, tens and hundreds. The thousands are counted by flip-flop IC410. The clock pulses are applied to the counter via gates IC414/B and IC414/D. Gate IC414/B can be blocked by applying an 0-signal to input IC414/4. By means of the reset pulse the counter decades are reset by applying a "1" signal to inputs 2 and 3 via lines R1 and R2.

At the same time gate IC413/A produces an 0-signal for the thousands flip-flop IC410/A, which is set to $Q = 0$. After counting 1000 pulses during the first programme cycle, the counter will be exactly at 0000 and is ready for the second programme cycle. The counter result (IC407 ... 409) is available on outputs 12 (A), 9 (B), 8 (C) and 11 (D) for further processing.

VII-4.11. Memory

The counter decades are used for measuring the upward and the downward integration time during each measuring cycle. To ensure convenient and jitter-free reading of the measuring result, the instantaneous measuring result should be stored until the next measuring value is supplied.

Storing takes place in three Quadruple bistable latches (IC404 ... 406) and one J-K flip-flop (IC410/B). During the transfer pulse these flip-flops are connected to the counter decades with an "1"-signal on clock inputs 4 and 13, or 5 for IC410, and the measuring result in BCD-code is then transferred from the counting decades to these flip-flops. The transfer pulse is produced by gates IC418/A and IC418/C.

By applying a 0-signal to input M of IC418/C continuous transfer is possible for testing purposes. The memory is then disabled and the display tubes will directly follow the instantaneous counter position.

VII-4.12. Decoding and display section

The output signals of the memory, which are available in the 1-2-4-8 code, should be converted into digits 0...9 and displayed. Decoding is effected in IC401...403, which moreover comprise the switching amplifier for driving the cathodes of indicator tubes B401...403. Tubes B404 (1000), B405 and the lamp "OVERLOAD" are driven by transistor amplifiers.

As the polarity indication and the a.c. sign depend on the mode of operation, the relevant indications are controlled by push-button switches AC (SK/II) and DC/R (SK2/III). The a.c. symbol is directly switched on and the polarity indication via AND-gates GR410/GR411 for the + sign or GR412/GR413 for the - sign.

VII-4.13. Automatic range selection

The automatic range selector supplies the control signals for the three reed relays in the analogue section which automatically change over the sensitivity in three steps of 1:10:100.

The change over points lie at 1998 and 180 units, which are derived from the counter. Digital values higher than 1998 cause changing over to the next less sensitive range; if no such range is available, pilot lamp "OVERLOAD" will light up.

This indicates that the measuring value has exceeded the specified limits and that the next higher range should be selected manually. In the case of digital values below 180 the automatic range selector changes over to the next more sensitive range. At the most sensitive range the reasing will be maintained.

The range selector also triggers the delay circuit via IC419/A ("D" pulse) during every step of the automatic range selector. The delay circuit provides a delay of approx. 100 msecs and serves to delay the measuring programme in order to allow the DC or AC pre-amplifiers to respond to the new measuring value. The switching information (> 1998 and < 180) is programmed by means of gates which are connected to the counter outputs. For measuring values greater than 1998 units the four gates IC413/A...IC413/C and IC418/B are operative and for values smaller than 180 IC411.

< 180 (output "Z").

This output signal is obtained from the memory by means of signals $\bar{B}$, $\bar{C}$, $\bar{D}$ from the "hundreds" decade, Q of the "thousands" decade and IC413/D.

At counter positions < 180 the 6 inputs of IC411 are "1", so that a 0-signal arises on the output of IC411. The table in Fig. 32 shows that for all the other counter positions at least one input of IC411 has zero potential so that a "1" will arise on the output.

> 1998 (output "Y").

At a measuring quantity larger than 1998, IC418/B will supply a 0-signal to the input of IC413/C. As a result, the output of IC413/C will be "1". In all the other situations both inputs will be "1", so that the output will be 0. IC413/B supplies the complementary signal to IC413/C.

The signals from the counter which contain the information necessary for operating the relays, should be processed in a decoding circuit, together with the positions of flip-flops IC422/A (A-FF) and IC422/B (B-FF). The decoding circuit consists of NAND gates IC419/B, $-/C$, $-/D$, IC420/B, $-/C$, $-/D$ and IC421, whose output signals control the A-FF and the B-FF so that the desired reed relay is operated or lamp "OVERLOAD" lights up.

The output signals of FF-A and FF-D (IC422/A and $-/B$) are again decoded by means of gates (GR419...425) which supply the control signals for the switching amplifiers TS417...TS420

	Output IC413/D	B	C	D	Output IC413/C (X)	1000's Q	Output IC413/B (Y)	Output IC411 (Z)
0	1	1	1	1	1	1	0	0
100	1	1	1	1	1	1	0	0
179	1	1	1	1	1	1	0	0
180	0	1	1	1	1	1	0	1
200	1	0	1	1	1	1	0	1
300	1	0	1	1	1	1	0	1
400	1	1	0	1	1	1	0	1
500	1	1	0	1	1	1	0	1
600	1	0	0	1	1	1	0	1
700	1	0	0	1	1	1	0	1
800	1	1	1	0	1	1	0	1
900	1	1	1	0	1	1	0	1
1000	1	1	1	1	1	0	0	1
1100	1	1	1	1	1	0	0	1
etc.								
1800	1	1	1	0	1	0	0	1
1900	1	1	1	0	1	0	0	1
1998	1	1	1	1	0	0	1	1
1999	1	1	1	1	0	0	1	1

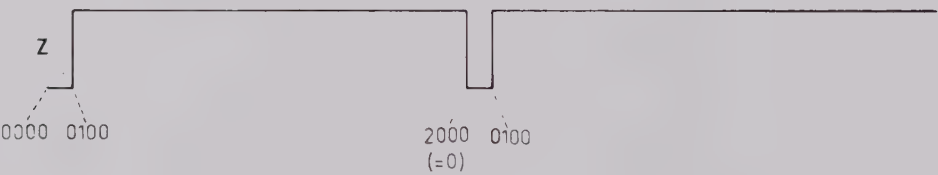


Fig. 32 The "Z" signal (< 180)

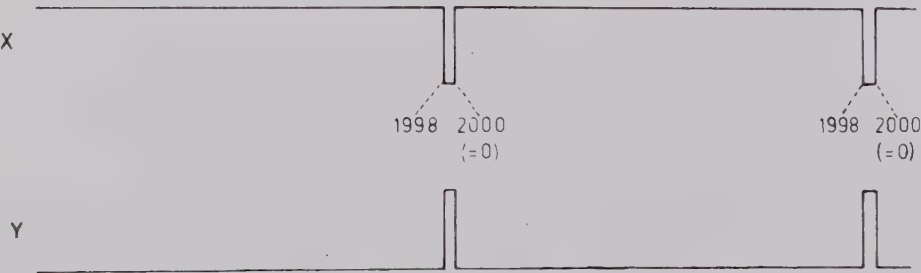


Fig. 33 The "Y" signal (> 1998)

	1	2	3	4	5	6	7
	Range not changed	Range change upwards	Range change downwards	Range -FF (IC422) A B Y Z	>1998 <180	Range -FF (IC422) A _{n+1} B _{n+1}	FF-Inputs (IC422) A _D B _D
a	10			0 0 0 0		0 0	0 0
b	10			0 0 0 1		0 0	0 0
c	100			1 0 0 1		1 0	1 0
d	1000			0 1 0 1		0 1	0 1
e	Overload			1 1 1 1		1 1	1 1
f		10 100		0 0 1 1		1 0	1 0
g		100 1000		1 0 1 1		0 1	0 1
h		1000 Overl.		0 1 1 1		1 1	1 1
i			Overl. 1000	1 1 0 1		0 1	0 1
k			Overl. 100	1 1 0 0		1 0	1 0
l			1000 100	0 1 0 0		1 0	1 0
m			100 10	1 0 0 0		0 0	0 0

Fig. 34 Truth table of automatic range selector

In table 34:

- Columns 1,2,3 : Kind of range selection
- Column 4 : Position of FF-A and FF-B before the transfer pulse.
- Column 5 : Control signals Y (>1998) and Z (<180) from the counter, which determine whether range change-over is necessary.
- Column 6 : Position of FF-A and FF-B after the transfer pulse.
- Column 7 : The control signals D which should be applied to flip-flops A and B to obtain the desired change-over.
These signals are produced by gates IC419...421.
- Transfer : This pulse is supplied by the programme circuit after completion of the measuring cycle. The flip-flops of the automatic range selector are operated by the positive edge of the transfer pulse.

No range selection

The measuring range is correct, i.e. the measuring result lies between 180 and 1998.
The control signals "Y" and "Z" are 0, and the flip-flops remain in the same position (lines a,c,d).
Besides, switching to another position is impossible when the range selector is already at the highest or lowest range and the measuring value is below 180 or above 1998 (lines b and e in the table of Fig.34).

Switching to a higher range

This control signal is given when the counter measures a value $\geq$ 1998. Input Y will then be 1 (lines f, g and h).

Switching to a lower range

This control signal is given when the counter measures a value < 180. Input Z will then be 1 (lines i, k, l, m of the table in Fig. 34).

VII-4.14. Relay drivers (Fig. 36)

The relay drivers serve to amplify the signals from the automatic range selector to drive the relays. The output levels of flip-flops A and B (IC422) are decoded by means of diode gates GR419...425. The control signals are applied to switching amplifiers TS417...420. When the inputs are 1 the amplifier will be operative and the relevant relay will be energised. Simultaneously, the decimal points in the indicator tubes will light up.

AC - DC change-over:

Range relays A, B and C are allocated to outputs A, B and C in accordance with the mode of operation of the instrument.

Changing over is effected by the AC/DC mode selector (SK2/II/III).

Arrangement of relays:	Range	AC mode	DC mode
	10	A	C
	100	B	B
	1000	C	A

Manual operation:

If required, the automatic range selector can be overridden.

The measuring range is selected via switch SK3 at the rear of the instrument. Yet, the range selection logic will remain operative because it drives the Overload lamp. As the logic must effect four steps to switch on the overload lamp, the lamp will light up with a delay of up to 1 sec.

VII-4.15. Clock pulse generator (Fig. 35 and 36)

Astable multivibrator TS413/TS414 produces the clock signal which has a frequency of 10 kHz. IC414/C operates as an isolating amplifier.

Working:

Assume TS414 is turned on. The negative voltage transient (1) is transferred to the base of TS413 via C418. As a result the base potential becomes approx. 0 (2).

The capacitor is then charged via R457 and R_x (3). Emitter-follower TS413 follows this voltage and is turned off when U_E is reached (4).

TS414 is also turned off (5) and the positive voltage transient on the collector of TS414 is transferred via C418 to the base of TS413 (6) due to the feedback. The capacitor is discharged via R457/R (7) until TS413 is turned on again (8). As a result TS414 is also turned on (9) and the process is repeated.

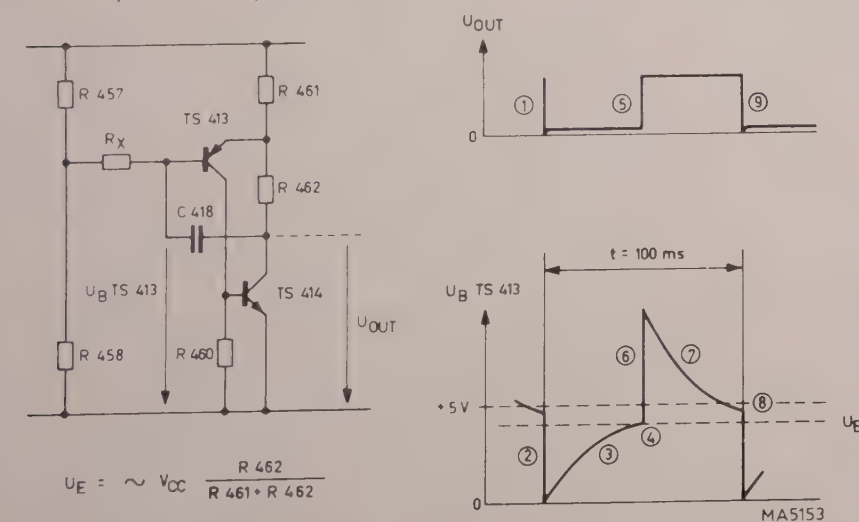


Fig. 35 Astable multivibrator

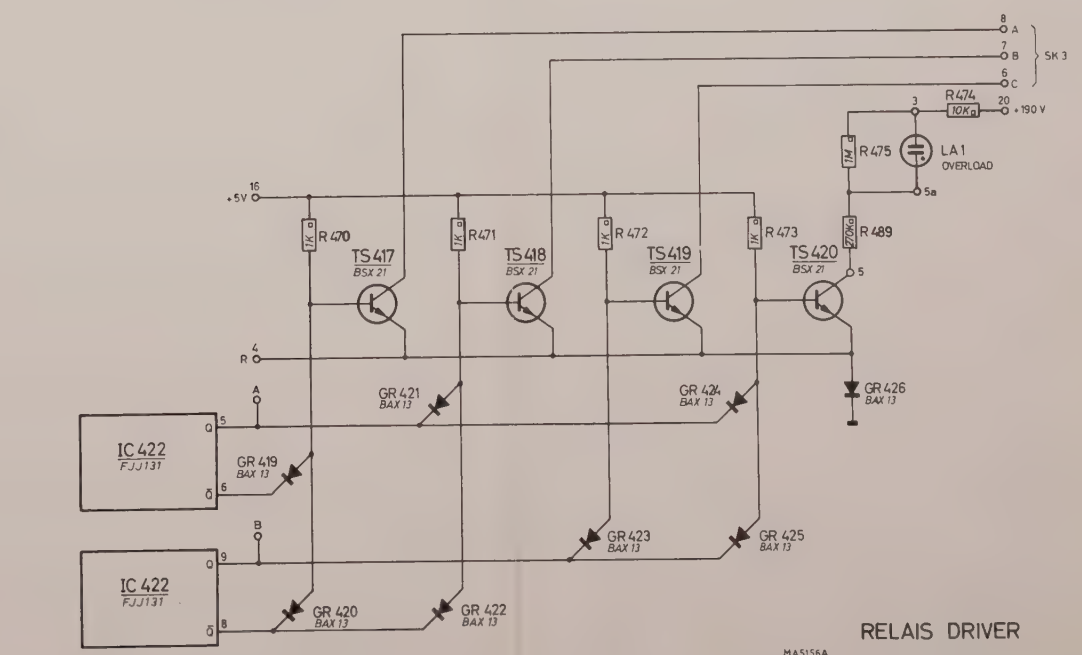
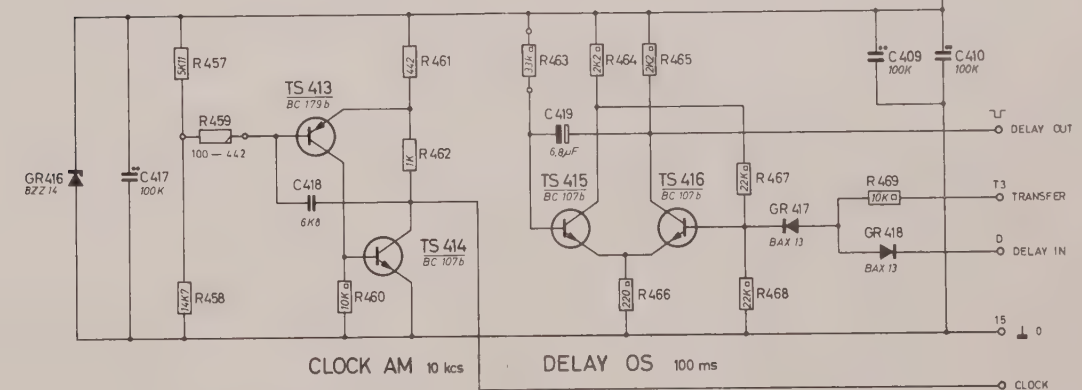
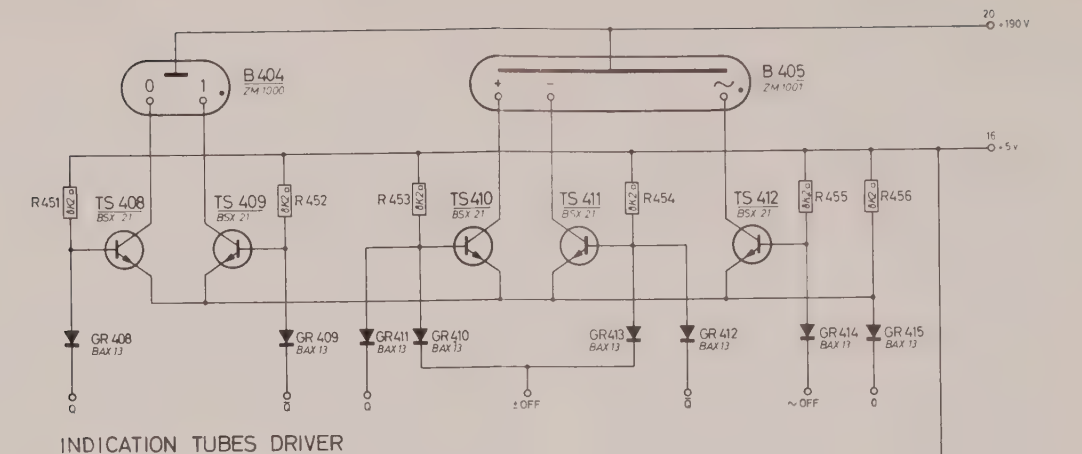


Fig. 36 Circuit diagram indication tube driver, clock oscillator, delay circuit and relay driver

The frequency is determined by R457, R458, R461, R462 and C418.
Adjustment is effected with the aid of R_x . The circuit has been designed so as to obtain a temperature coefficient of 100 ppm/C.

VII-4.16. Delay circuit (Fig. 36)

This circuit serves to delay the programme approx. 100 msecs when the automatic range selector has effected one step. The delay is necessary to allow the pre-amplifiers (AC, DC, HF etc.) to adapt themselves to the new measuring value.

The monostable multivibrator is of the conventional design. In the rest position TS415 is turned on via R463 and TS416 is turned off. If "1" signals are applied to inputs T3 and D. transistor TS416 is turned on and switches the monostable multivibrator to its quasi-stable position. The duty cycle is determined by means of R463 and C419.

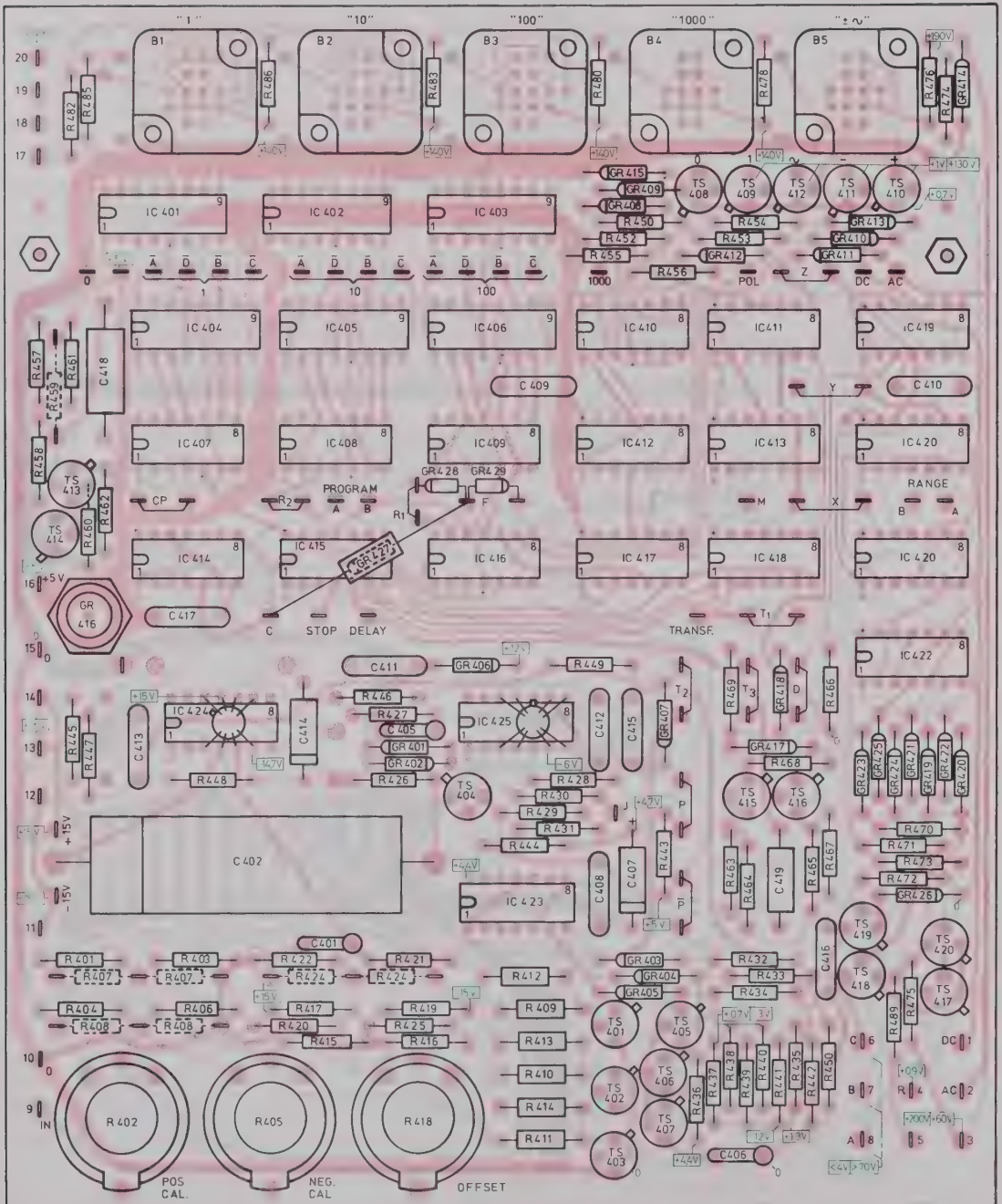


Fig. 38 Printed circuit board U4

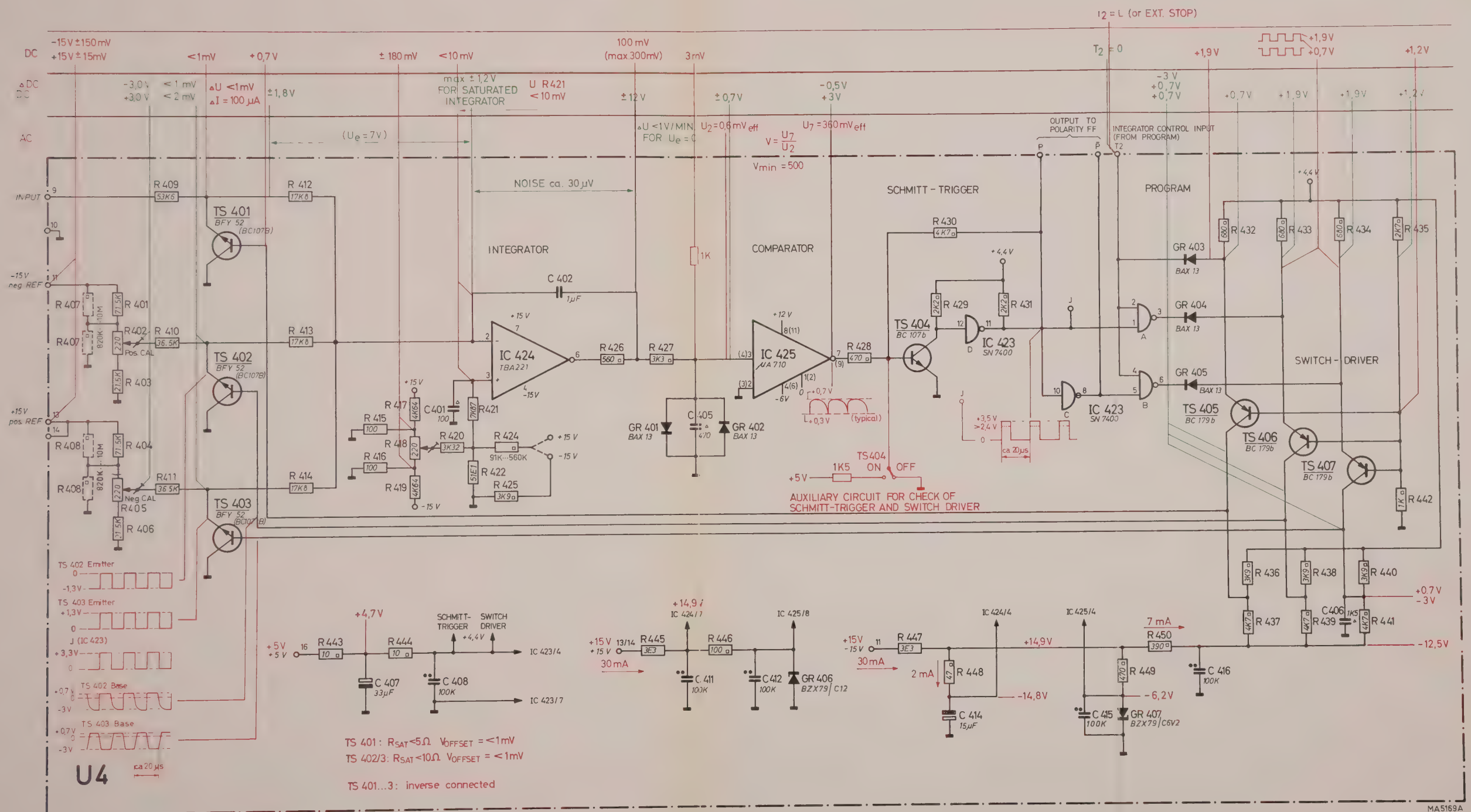


Fig. 37 Input circuit of the digital part

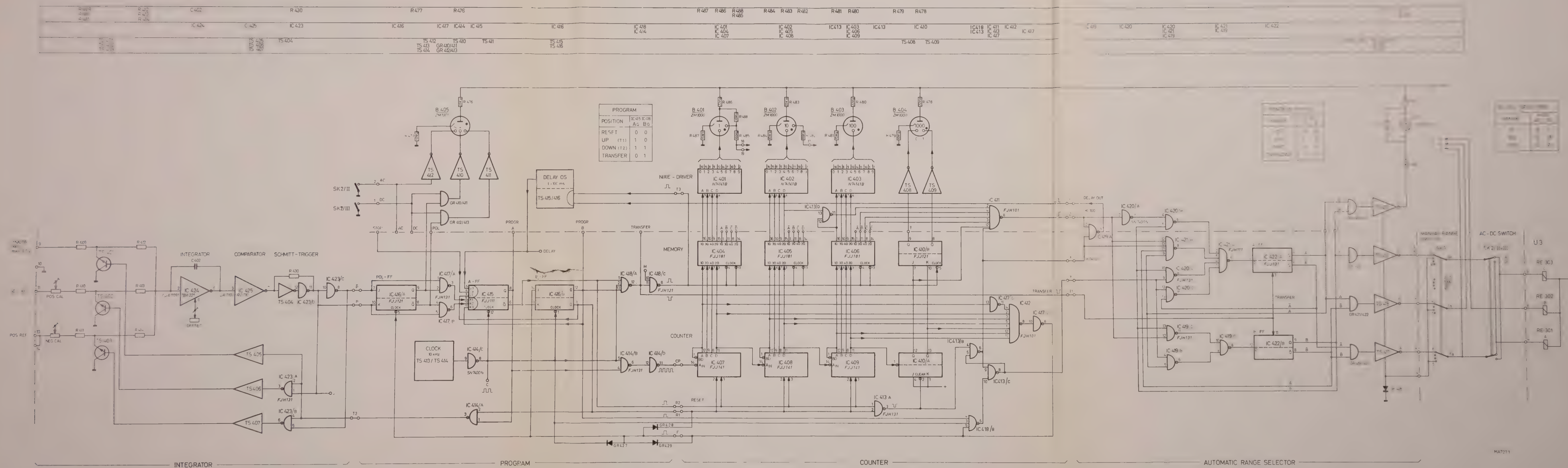


Fig. 39 Logic circuit diagram of the digital section

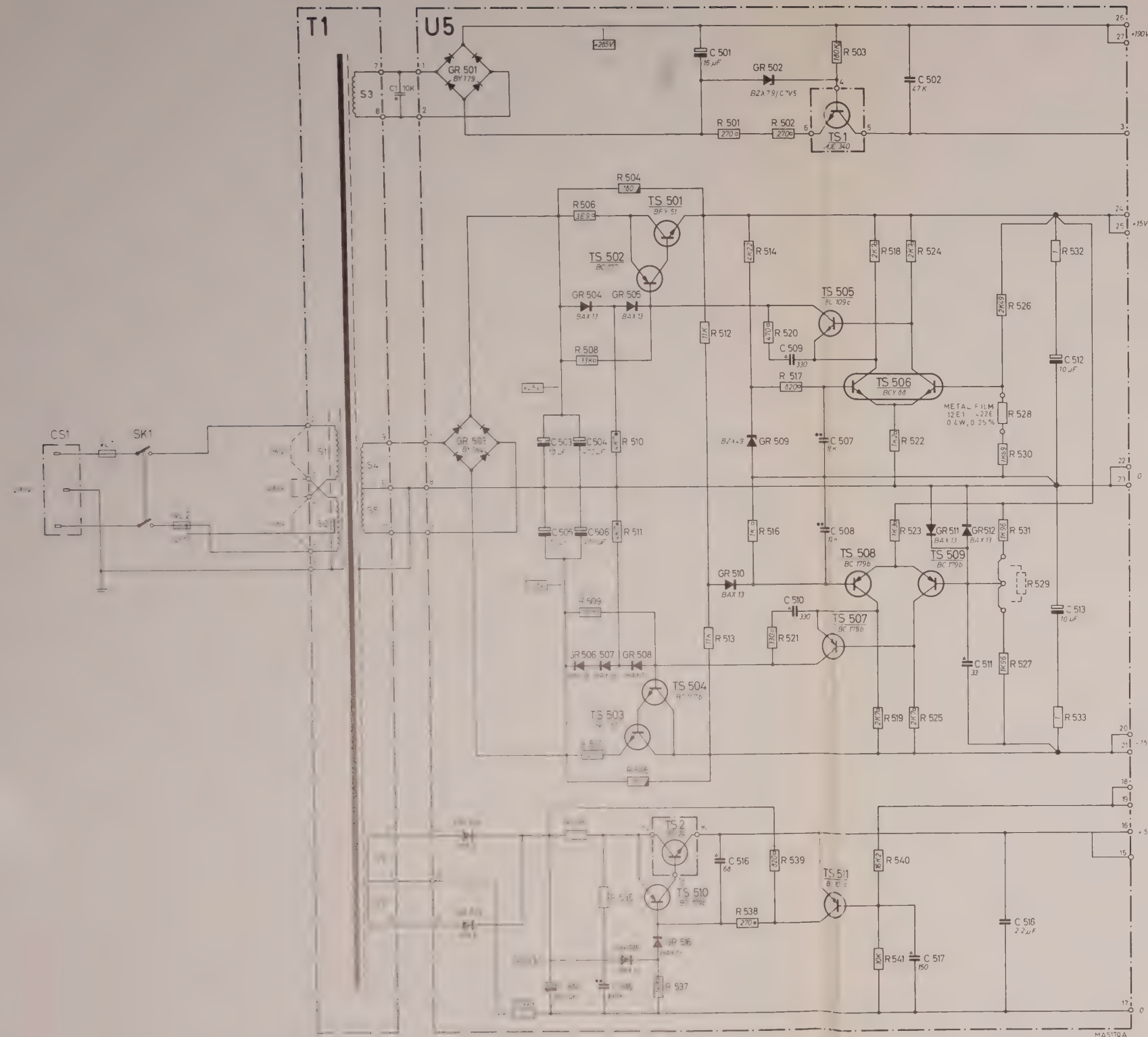


Fig. 41 Circuit diagram supply section

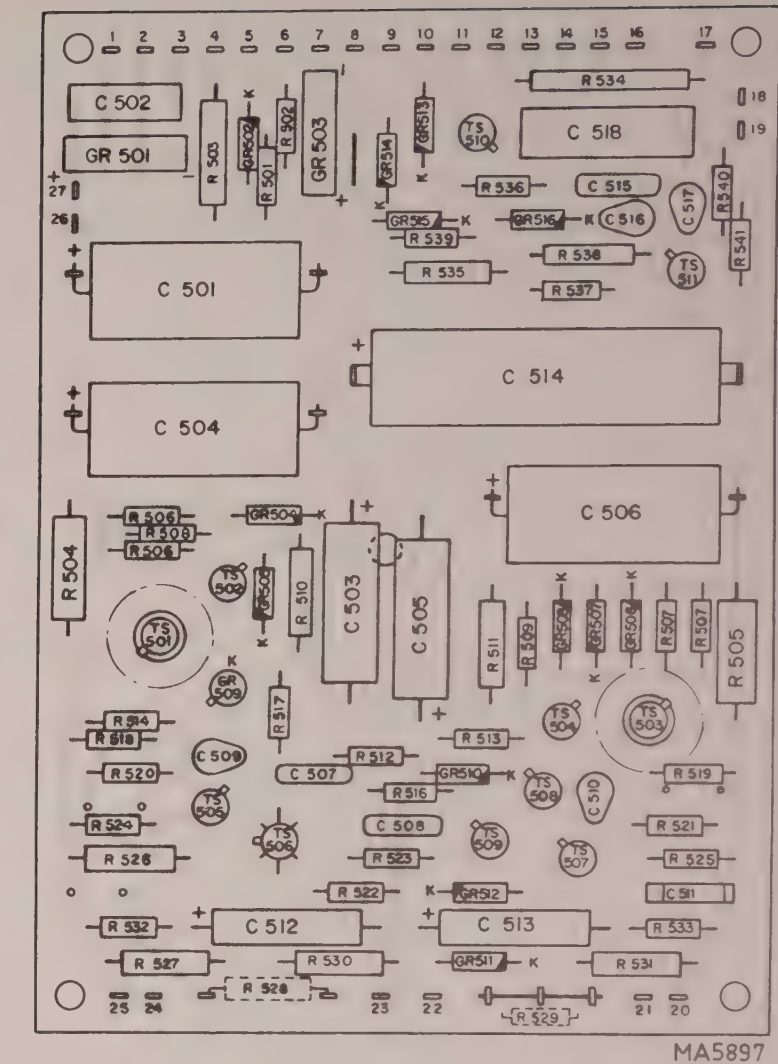


Fig. 40 Printed circuit board U5

VII-5. SUPPLY SECTION (U5) Fig. 41

The instrument comprises four stabilised supply sources.

The indicator tubes and the chopper lamps are supplied with a voltage of approx. 190 V. This source is only current stabilised. The output current of this stabiliser is adjusted so that the voltage drop across zener diode GR502 and the voltage drop across the base-emitter junction of TS1, R501 and R502 are equal. As the total current consumption of the lamps does not change, the voltage on the output will be constant.

The positive and the negative 15 V voltages do not only serve as supply sources but also as reference sources for the integrator.

The long-term stability and the low temperature coefficient are achieved by using one reference diode (GR509) and by using precision wire-wound resistors for all the critical voltage dividers.

The positive output voltage is divided by resistors R526, R528 and R530 in such a way that both sections of TS506 have the same base voltage. When the output voltage decreases (due to an increasing load or due to a decrease in mains voltage), the voltage on the right-hand base of TS506 will be smaller than the reference voltage across GR509. This base voltage then causes a collector current decrease, so that the base voltage of TS505 will increase.

After being amplified twice and after phase inversion the voltage on the base of TS501 will also increase. This emitter-follower then compensates for the original voltage drop because its collector-emitter resistance decreases. The circuit is short-circuit proof, i.e. the series regulators are automatically disconnected.

When the voltage drop across R506 is larger than that across GR505 (the base-emitter voltage of TS502 is compensated for by GR504), the current through TS502 and, consequently, that through TS501 will be limited. The circuit has no thermal protection against prolonged overloading.

The working of the stabilisation and the short-circuit protection of the negative 15 V supply is similar to that of the positive section. In this case the circuit zero serves as a reference and the voltage divider is included between the positive and the negative output.

The reference voltage for the +5 V supply is derived from the +15 V source by means of voltage divider R540 and R541. In case of a short-circuit the voltage drop across R535 will exceed the threshold voltage of GR516; thus the currents through transistors TS510 and TS2 are limited. The integrated circuits in the digital section are thus protected against excess voltages in the 5 V supply. Moreover on digital unit U4 zener diode GR416 is connected in parallel with the 5 V supply.

VIII. Access

VIII-1. Removing the cabinet (Fig. 42)

The instrument chassis is constructed as a compact plug-in chassis and is accommodated in a 3-module standard cabinet. The chassis can be pulled out of the cabinet by means of the two locking devices at the front. When these locking devices cannot be hinged out, the two locking screws at the front should be loosened (do not remove them) by means of the 2.5 mm Allen key, included in delivery. The chassis can then be pulled out of the cabinet.

Caution: Pull out the mains plug before removing the chassis out of the cabinet.



Fig. 42 Pulling the instrument chassis out of the cabinet

VIII-2. Electrical parts

To replace the components on the printed circuit boards, the relevant printed circuit board should be taken out. The connection wires are provided with AMP-connectors and can be pulled out individually. Do not pull at the wires but hold the connector at the clamped part with flat-nosed pliers and pull it out perpendicular to the board. Note the wire colours!

VIII-3. Push-button switch

Replacement of the complete push-button assembly should only be effected when strictly necessary. This is because it is possible to replace the contact assembly of each button individually. For this purpose all the connection wires should be unsoldered from the contact plate (note connection and wire colour, see Fig. 54). Slightly compress the relevant tags; the wafer together with the cursors can then be taken out.

Caution: When taking out the contact plate check that the button is depressed. Otherwise the button will pop out and cannot be refitted due to the locking plate at the front. It is therefore recommended to hold the push-button in place by means of adhesive tape at the front so that it cannot drop out.

The plastic slide which operates the contacts can be replaced after removal of the contact plate. The contact plates are not separately available, only the complete set of push-buttons is supplied (see List of mechanical parts for the code number). However, it is possible to fit the contact plate of the new push-button assembly in the assembly already mounted. This procedure is much simpler than replacing the complete push-button assembly.

VIII-4. Semiconductors

- a. Transistor TS401 (ordering number 5322 130 40505) is a selected transistor, type BFY52 (or BC107). This transistor has been selected with the following specifications:
 - Leakage current $< 1 \text{ nA}$
 - Offset voltage $< 1 \text{ mV}$
 - Offset resistance $< 5 \Omega$
- b. Transistors TS402 and TS403 (ordering number 5322 130 40506) are selected transistors, type BFY52 (or BC107). These transistors have been selected with the following specifications:
 - Leakage current $< 1 \text{ nA}$
 - Offset voltage $< 1 \text{ mV}$
 - Offset resistance $< 10 \Omega$
- c. Diode GR509 (ordering number 5322 130 30742) is a selected diode type BZX49. This diode is selected for hum ($< 50 \mu\text{V}_{\text{rms}}$ at a current of 2 mA) and stability ($\leq \pm 5 \mu\text{V}$).

VIII-5. Capacitors

- . Capacitor C402 can also be replaced by a standard capacitor, ordering number 4822 121 40013, but this capacitor may only be used if the instrument is not used in measuring systems.

IX. Maintenance and service

Digital voltmeter PM 2421 requires no maintenance because the instrument contains no components which are subject to wear.

However, to ensure reliable and faultless operation, the instrument should not be exposed to moisture, heat, corrosive vapours and excessive dust.

Service hints

To enable rapid servicing, the printed circuit board on which the defect is located can be readily replaced. This procedure is greatly facilitated by the simple construction and the use of wiring connectors.

If service work is to be carried out the following points should be taken into account to avoid damage to the instrument.

- When working on an instrument from which the cabinet has been removed, always pull out the mains plug. (When the mains switch is set to the off-position, the mains voltage is still present on fuse VL1 on the mains transformer, with the consequent risk of shocks).
- In the case of measurements on a switched-on instrument proceed carefully to avoid short-circuits by means of measuring clips or measuring hooks. The measuring connectors stated in chapter XIII are extremely suitable for test purposes. When connecting test plugs, always switch off the mains-voltage.
- For soldering use absolutely acid-free solder.
- The IC-circuits are especially sensitive to negative potentials, which will damage the IC.
- For all soldering work on the printed circuit boards, use a miniature soldering iron, if possible a vacuum soldering iron.

X. Fault finding

X-1. GENERAL

The division of the digital voltmeter into functional units, which are both electrically and mechanically separated from each other, permits of efficient and systematic fault-finding in case of a defect.

The link between the various functional sections is formed by the push-button assembly which interconnects the various circuits.

The fault may already be located roughly by checking whether the fault is restricted to a single mode of operation. If the display section is suspected, it suffices to check the voltage on the analogue output (BU9 and BU10) by means of a proper d.c. voltmeter. The voltage on these sockets should be exactly 3.5 mV per digit. For a reading of , for example, 1000 (independent of the measuring range) the output voltage should be 3.5 V.

When the output voltage on BU9 and BU10 corresponds to the digital reading, the integrator and the display section of the instrument will be in order.

Thus, the fault source can be traced down to a certain functional section, i.e., d.c. amplifier U1, a.c. amplifier U2, HF section U3 or digital section U4. However, the supply section should be in order, which can be determined by measuring the supply voltages.

X-2. D.C. AMPLIFIER U1

- Depress buttons "DC/R" and "mV"

Checking the amplifier output

- Without input signal the output voltage on point 10 should be 0 ± 3 mV; the zero-setting can be adjusted with R2 (0-control on the front).

Checking the chopper drive

- Check the signal on the collector of TS109 and TS110 of the astable multivibrator. A square wave voltage should be present ($1.8 \text{ kHz} \pm 5\%$) (Fig. 43).

Checking the demodulator

- The signal on the junction of R118 and R120 should be in accordance with fig. 44.

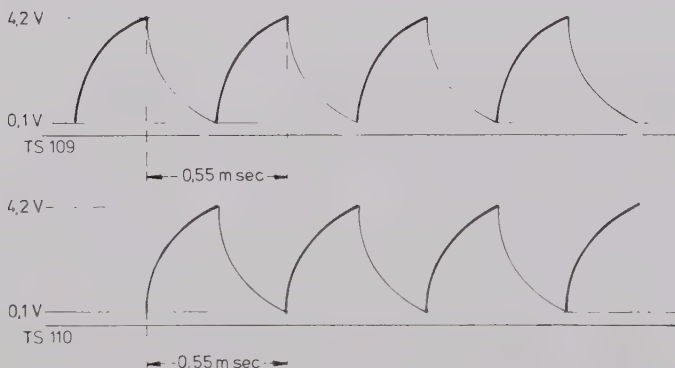


Fig. 43 Collector signals of TS109 and TS110



Fig. 44 Output voltage demodulator

X-3. A.C. AMPLIFIER U2

- Depress buttons "AC" and "mV"
- Measure the voltage on the base of TS210; this should be $-3\text{ V} \pm 1\text{ V}$
- With short-circuited input the output voltage on point 23 should be $0\text{ V} \pm 5\text{ mV}$
- The voltage on the plus pole of C207 should be $+0.5 \dots +3\text{ V}$.
- Apply 100 mV a.c. to BU6 and BU7; this voltage should also be present on point 1
- The voltage on point 25 should be 10 mV and the voltage on the base of TS207 approx. 170 mV $\pm 10\%$
- Check the waveform on GR208 with an oscilloscope and measure the voltage across GR211 and R244 or R241 and R242; this voltage should be 0.5 V
- There should also be a voltage difference of 0.5 V between the emitters of TS213, and the voltage on the output, point 23 should be 5 V with respect to $\perp$.

X-4. H.F. SECTION U3

Current generator

- Depress buttons "DC/R" and " Ω "
- Measure the current across BU2 and BU3 with a second PM 2421.
This should be 1000 μA .
- Check the base voltages of TS306; these should be equal ($-10\text{ V} \pm 1\text{ V}$ with respect to $\perp$).
Deviation with respect to each other $< 20\text{ mV}$. Otherwise, there is a defect in the circuit (TS307...TS309).

Oscillator

- Depress buttons "HF" and "mV", do not connect the probe
- Unsolder the wire from point 27 and apply a voltage between 0 and -600 mV d.c. to point 27
- At 0 V the voltage measured on point 15 should lie between 0 and 20 mV (300 kHz).
- When -600 mV is applied to point 27 the voltage on point 15 should be min. $1.5\text{ V}_{\text{rms}}$
- Check the oscillation on C203
- Connect the measuring probe and carry out the calibration (as described in chapter VI.9).
If one of the diodes in the probe is defective, calibration will be impossible.

Relay drive

- Switch over SK3 manually and observe the decimal point
- ± Depress button "AC"
- Apply an alternating voltage of 1 V to BU6 and BU7
- The voltage on point 5 should be 1 V, across R341/R342 100 mV, and across R342/R343 10 mV

NOTE: The voltage divider R340...R343, which is switched-in by the automatic range selector, is composed of 0.1% resistors. In some cases, resistors R341 and R342 are just within tolerance but not accurate enough for the PM 2421.
In these cases adjusting resistors have been mounted in parallel with R341 and R342.

X-5. DIGITAL SECTION U4

To facilitate fault-finding in the digital section, the fault-finding system of Fig. 45 may be used. This series of measurements is the most efficient method to trace the defective section. The individual tests are further described in the instructions below.

X-5.1. Test of analogue input, supply and clock signal

Before checking the digital section first check:

- a. the analogue input voltage (see XII-10)
- b. the supply voltage (see XII-1)
- c. the clock signal (see XII-2.2.4).

X-5.2. Fault-finding in the analogue-to-digital converter

Determine whether the fault is located in the measuring section (ADC) or in the automatic range selector.

Disable the automatic range selector with SK3 and apply approx. 500 units, and 180 and more than 1998 units. Check the reading and the working of the automatic range selector.

X-5.3. Checking the programme flip-flops A and B

Apply an input voltage of 0...500 units.

Check the programme run-down, the oscillogram (Fig. 24, page 88) and the truth table (Fig. 30, page 93). Trigger flip-flop A, IC415/8 with positive or negative edge.

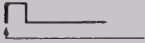
For locating faults in the programme circuit it may be necessary to external control the inputs "ZERO", "1998" (F), and "STOP". Thus the individual programme steps can be checked (except the Transfer-Reset transition).

X-5.4. Checking the control signals ("1998", Zero, Stop)

- 4.1. Clock signal: Check the signal on IC415/12 and IC416/B/1; the frequency should be approx. 10 kHz, $T = 100 \mu\text{secs}$.
- 4.2. Pulse signal "1998".

Condition: The counter should operate properly (see Counter, if necessary, check 1:10 ratio).
Oscillogram: Input voltage = 0, if necessary, disconnect delay circuit.

Outputs:

IC417/8 "1998" (F)  Triggering is effected on the positive edge of the 1998 pulse.
IC412/8 "1998" (F) 

Inputs:

IC417/13	"1"	(A)	
IC412/4	"1"	(A)	
IC412/2	"8"	(D)	
IC412/3	"10"	(A)	
IC412/5	"80"	(D)	
IC412/12	"100"	(A)	
IC412/11	"800"	(D)	
IC412/1	"1000"	(T)	

Fault symptoms:

- Several "1998" pulses
Reading e.g. 1992 at input voltage = 0: fault in one of the input circuits of IC412.
- No "1998" pulse (programm circuit in position "Upward")
One input of IC412 is permanently connected to earth.
- "1998" pulse has a duration of 200 μ secs
This results in incorrect triggering of the polarity flip-flop at a small input voltage.
Cause: $\bar{A}$ fails on input IC412/4.

4.3. "ZERO" signal (input voltage = 0)

Check the switching conditions of IC415 during zero passage.

IC415/9 (K1)		or		TRIGGER
IC415/10 (K2)				
IC415/11 (K3)				

Possible faults: "1998" (F)

- One polarity cannot be measured (IC415/5 continually 1).
- Check polarity flip-flop IC416/A.
- The programme circuit is in position "Downward" (IC415/4 or IC415/5 continually 0).
Check polarity flip-flop and integrator.

4.4. "STOP" signal

Switching conditions:

IC415/4 should not be connected or be "1" (by means of external stop signal)

IC415/5 should be 1 (from delay circuit)

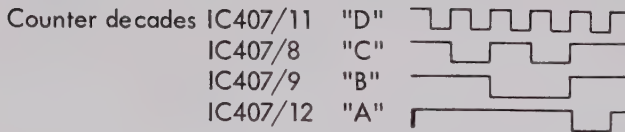
- Possible faults:
- Programme stops at reset
 - Delay during range selection inoperative.

X-5.5. Measuring or reading errors

- Reading errors $\longrightarrow$ check counter etc.
- Measuring errors $\longrightarrow$ check integrator.

X-5.6.1. CounterAdjustments:

- Block the programme circuit in position "Upwards" 1998 = 0
- Switch on memory permanently: M = CP
- Connect an external clock generator $f = 1 \text{ Hz} \dots 1 \text{ kHz}$ to CP.

Check:

Also check IC408 and IC409 in the same way.

Trigger on negative edge of "D".

Check Reset: Adjustment: R1 = 1, R2 = 1

Check : All counter flip-flops at 0 (A, B, C, D)
IC410/13 = 1 (1000)

6.2. Memory

Adjustment: M = 0 Memory follows counter → same oscillogram as under "Counter decade".

M = 1 Result is stored.

Output signals:

Signals of < 180, ≥ 1998, "1998" can be statically checked (see truth table, Fig. 32-33, page 97)

6.3. Drivers and indicator tubes

- Check the reading while applying corresponding input voltages
- By holding an oscilloscope probe at approx. 5-10 mm from one of the drivers, this can be checked for oscillation.

X-5.7. Integrator

Check + 15 V, -15 V and 0 V supply, and check printed circuit board for interruptions etc.

7.1. By adjusting T2 to 1 practically the entire integrator can be checked (see Fig. 37, page 104 red indications).

TS401 Excessive offset / leak resistance, insufficient drive current

IC424 Excessive offset, excessive quiescent current, offset network

TS425 Offset, quiescent current, gain

TS404 } Schmitt trigger
TS423 }

TS405 } Switch driver network
TS406 }
TS407 }

Non-linearity
No adjustment
Temperature coefficient too large
Too large hysteresis
Zero frequency too low (should be 50 kHz).
Unstable reading at small positive input voltage
Non-linearity (error at full-scale value)

If one of the above-mentioned components or networks is defective, the integrator will be driven into positive or negative saturation → Locate error.

If this is impossible, the circuit may be controlled at the input of the Schmitt trigger (see Fig. 47, page 129).

This enables static fault-finding in the Schmitt trigger, switch-drivers etc.

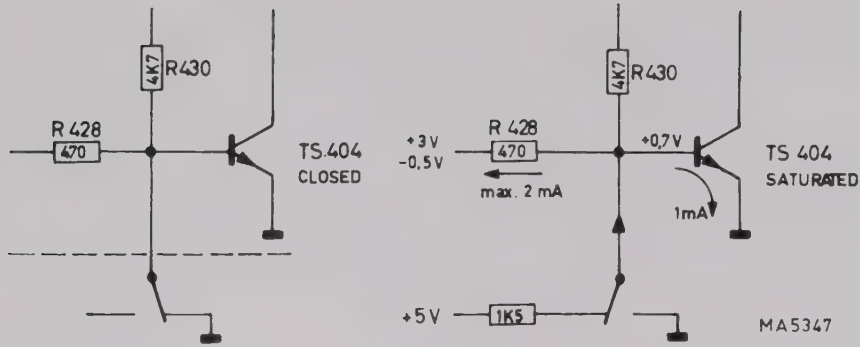


Fig. 46 Applying an external signal to the Schmitt trigger

7.2. Adjustment $T_2 = 0$ (see Fig. 37, page 104, green indications)

The input is disconnected from circuit zero (TS401 cut off), the reference voltage is switched off.

This will enable static fault-finding in the following circuits:

TS401/TS402/TS403
IC424

Input switches/switch drivers

Integrator:

At V_{in} (input voltage) = 0 (9), V_{out} = (output voltage) constant (adjust with potentiometer R428, Offset)

Drift should be less than 1 V per minute.

Oscillations cause non-linearity.

By slowly varying the integrator output from -12 V to +12 V ($V_{in} = 5$ mV) and checking the output voltage with an oscilloscope and voltmeter, deviations can be detected.

Cause:

E.G. blocking capacitor C411 or C414 defective.

Measure the gain of the operational amplifier.

Connect the integrator as an amplifier.

$R_p = 71K4$ parallel to C402. $V = -1.0$ (for DC)

Measure the open-loop gain

$V_{in} = 5$ V_{rms} $f = 5$ Hz

$U_a = \text{approx. } 2$ V, gain min. = 15000 → non-linearity

$U_2 = < 150$ μ V (typical 60 μ V) Noise approx. 30 μ V.

This method can also be used to check the working of the comparator, its gain and the working of the Schmitt trigger (if necessary use high frequencies).

7.3. Automatic range selector

The working of the automatic range selector can be checked by checking the reading and the decimal points. Proceed in accordance with test scheme.

X-5.8. Range flip-flops A and B

Apply a direct voltage of $< 180 / \geq 1998$ units to the analogue input (9). Check whether the flip-flops change over properly (in accordance with truth table in the circuit diagram Fig. 39, page 109).

- X-5.9. Relay drivers (if test 8 yields correct result)
If necessary, load + 15 V with 705 Ω, depending on result.
- X-5.10. Decoder (in accordance with diagram Fig. 39, page 109)
- X-5.11. Relay inputs (in accordance with diagram Fig. 39, page 109)
11.1. Check relays RE301 ... RE303 on U3.
11.2. Check SK3, SK2/II/III.
If test 8 indicates incorrect operation of flip-flops A and B, proceed with point 12, 13 or 14, depending on symptoms.

- X-5.12. Does not change over
Coincidence of transfer signal T1, X, Y and Z.
Trigger on negative edge of T1.
- X-5.13. Changes over at incorrect input voltage
Check counter with signal < 180, ≥ 1998 (gates IC411/IC413).

- X-5.14. Incorrect sequences
Carry out static check of gates IC419...421 and FF422 in accordance with table below. For this, the three inputs X, Y, Z (if necessary T1) should be disconnected and external input signals should be applied in accordance with column "Input signal". To cause the flip-flop to change over, a single input signal should be applied to the automatic range selector via T1. This signal can be obtained with a button via T1 or by initiating a single measurement at the stop input.
Checking the automatic range selector:

	Positon before triggering				"Input Signal"			IC421				IC419			
	FFA FFB		DRIVER OUT		IC422										
	(IC422)														
	5	9	1	0	X	Y	Z	2	12	1	2	4	5	9	10
No change-over	0	0	A	1	0	1	0	0	1	1	1	1	1	1	1
	1	0	B	1	0	1	1	0	1	1	1	0	1	1	1
	0	1	C	1	0	1	0	1	1	1	1	1	1	0	0
	1	1	C+D	1	0	1	1	1	1	1	0	1	0	0	0
"UPWARDS"															
10 → 100	0	0	A	0	1	1	1	0	0	1	1	1	1	1	1
100 → 1000	1	0	B	0	1	1	0	1	1	1	1	1	0	1	1
1000 → OVL	0	1	C	0	1	1	1	1	0	1	0	1	1	0	0
"DOWNWARDS"															
OVL → 1000	1	1	C+D	1	0	1	0	1	1	1	1	1	1	0	0
OVL → 100	1	1	C	1	0	0	1	0	1	0	1	1	1	1	1
1000 → 100	0	1	B	1	0	0	1	0	1	0	1	1	1	1	1
100 → 10	1	0	A	1	0	0	0	0	1	1	1	1	1	1	1

Explanation:

- 1st column : Desired range selection (e.g. from range 10 to 100)
- 2nd column : Logic condition of the range flip-flop and relay drivers before trigger pulse T1 is applied.
- 3rd column : Input signals X, Y, Z which control the process indicated in column 1.
- 4th, 5th, 6th column : Logic levels on various points of gate network IC421/IC419.

If a fault is detected with aid of the table, the defect can be located via IC421/8 or IC419/20.

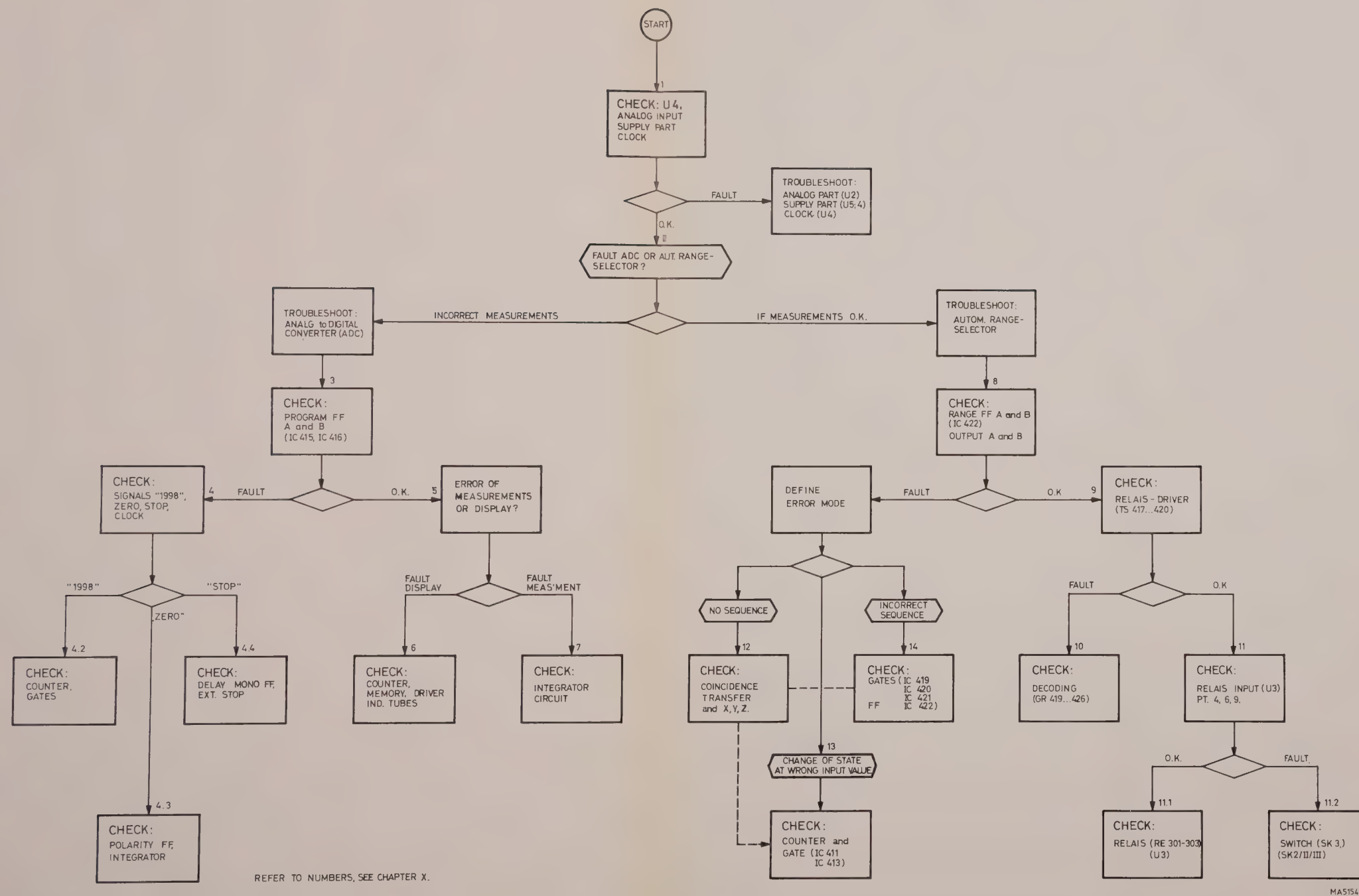


Fig. 45 Fault tracing survey

XI. Survey of adjusting elements

The following table gives a survey of all the adjustment of digital voltmeter PM 2421.

For a complete adjustment adhere to the sequence of chapter XII.

Adjustment no.	Adjustment	Adjusting element	Adjustment data
1.2	+ 15 V supply	R528	+ 15 V $\pm$ 0.3% (DC)
1.3	- 15 V supply	R529	- 15 V $\pm$ 0.3% (DC)
2.1	Digital zero adjustment	R418	
2.2	Nominal digital adjustment	R402 fine R407 coarse R405 fine R408 coarse	$\left. \begin{array}{l} \text{positive} \\ \text{negative} \end{array} \right\} 7 \text{ V } \pm 0.02\% \text{ (DC)}$
2.4	Digital clock frequency	R459	10 kHz $\pm$ 1%
2.5	Digital delay circuit	R463	100 msecs
3.5	DC amplifier (course) (fine)	R101 R102	DC nominal value 1.2 V $\pm$ 0.2%
3.8	DC amplifier	R340	DC nominal value 10 mV $\pm$ 0.05%
3.9	Offset current	R109	
4.4	High-ohmic voltage divider DC	R204	DC nominal value 10 V $\pm$ 0.02%
5.1	Ω ranges		
5.2	k Ω ranges	R5/R11	Nominal value 100 k Ω $\pm$ 0.1%
5.3	M Ω ranges	R12	Nominal value 10 M Ω $\pm$ 0.2%
8.1	Zero adjustment, AC Common mode rejection	R259	According to checking instructions
8.2	Sensitivity AC amplifier	R242 fine R225 coarse	Nominal value 1 V $\pm$ 0.05% 1 kHz
8.3	Frequency response	C210	Nominal value at 1 V $\pm$ 0.05% 1 MHz
	Frequency response	C209	Nominal value at 1 V $\pm$ 0.05% 300 kHz
	Frequency response	C212	Nominal value at 1 V $\pm$ 0.05% 600 kHz
8.4	High-ohmic voltage divider AC	C202 R205 R201 (C-adj.)	Nominal value 10 V $\pm$ 0.05% 300 kHz Nominal value 10 V $\pm$ 0.05% 1 MHz Nominal value 10 V $\pm$ 0.05% 5 kHz
8.5	Setting of TS207...TS209	R228	According to instructions
9.3	HF section	R337	Nominal value 1.3 V $\pm$ 1% 300 kHz
9.6	HF section	R331	Nominal value 2 mV $\pm$ 1% 300 kHz
	Offset adjustment	R410	
	DC zero adjustment (coarse)	R137	

XII. Checking and adjusting

The tolerances stated in this chapter correspond to the factory data, which only apply to a completely re-adjusted instrument. These tolerances may deviate from those mentioned in the Technical Data (Chapter II).

A survey of the adjustments and adjusting elements is given in chapter XI.

For a complete readjustment of the instrument the sequence in this chapter should be adhered too. When individual components, especially semiconductors, are replaced, the relevant section should be completely readjusted.

To calibrate this measuring instrument only reference voltages and measuring equipment with the required accuracy should be applied. If such equipment is not available, comparative measurements can be made with another calibrated PM 2421. However, theoretically the tolerances may be doubled in the extreme case.

The measuring arrangement should be such that the measurement cannot be affected by external influences. Protect the circuit against temperature variations (fans, sun).

With all the measurements the cables should be kept as short as possible; at higher frequencies coaxial leads should be used.

Non-screened measuring cables act as aerials so that the measuring instrument will measure HF voltage values or hum voltages.

For the accurate measurement of HF voltages which are to be used as reference for calibration, the method with thermocouple is extremely suitable. A combined measuring arrangement for DC, AC and HF voltage measurements is shown in Fig. 48 and the principle of this method is given in Fig. 49, page

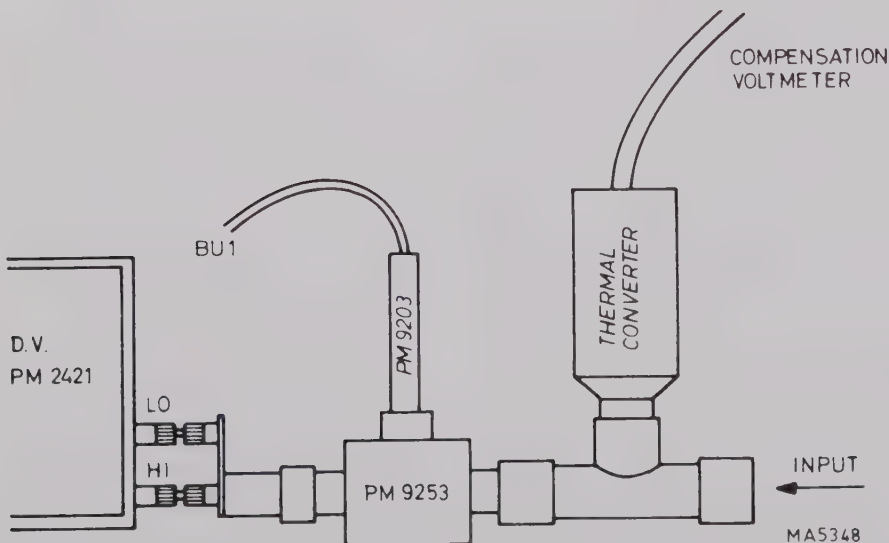


Fig. 47 Combined measuring arrangement set-up

XII-2. Digital section

2.1. Zero adjustment

- Pull the AMP connector from connection pin U4/9 and interconnect pins 9 and 10 (wire of connection 9 should remain free).
- Switch on the instrument and depress button "DC/R".
- Adjust potentiometer "OFFSET" (R418) so that the polarity indication alternately indicates + and -.

2.2. Adjustment to nominal value

- Remove the interconnection between pins 9 and 10 and apply a voltage of $7\text{ V} \pm 0.02\%$ to these pins (+ to point 9).

Attention: The digital section has a low input resistance, therefore no voltage dividers should be used.

- Adjust the reading to 1998 with potentiometer "POS. CAL." (R402).
- Check the linearity at some intermediate values, e.g.

$0.7\text{ V} \pm 0.02\%$	Indication: 200
$2.8\text{ V} \pm 0.02\%$	Indication: 800
$3.5\text{ V} \pm 0.02\%$	Indication: 1000
- Reverse the polarity of the test voltage applied ($7\text{ V} \pm 0.02\%$) at points 9 and 10, i.e. + to point 10.
- Adjust the reading to 1998 by means of potentiometer "NEG. CAL." (R405).
- Check the linearity according to 2.2. subpoint 3.
- If the control range of R402 or R405 is insufficient, adaptation is possible by means of shunt resistors R407 or R408 (Fig. 54, page 147).
- Refit the AMP connector on pin 9.

2.3. Checking the automatic range selector

- At a reading of 1000 digits or higher the decimal point indicator extinguishes.
- For checking the other switching actions, refer to point 6.

2.4. Clock oscillator frequency

- The 10 kHz clock frequency can be checked on connection point U4/C (or on IC414/C/8).
- Adjustment to $10\text{ kHz} \pm 1\%$ is effected with R459.

2.5. Delay circuit

- The delay time of one shot TS415/TS416 is determined by the RC ratio of R463/C419 and should be approx. 100 msec (normal tolerance of C419 is permissible).
- Adjustment is possible by selection of R463.

XII-3. DC amplifier

- Depress buttons "DC/R" and "mV".
- Interconnect input sockets BU6/BU7 with a short cable.
- Adjust the reading to zero by means of R2 (0 control).

- If the control range of R2 is not sufficient, an adjustment can be made with R137 (set R2 to mid position).
- Eliminate the short circuit between BU6/BU7.
Adjust the reading to zero by means of R109.
- Interconnect BU6/BU7 again.
Adjust to zero by means of R2.
- Eliminate the short circuit between BU6/BU7.
Adjust the reading to zero by means of R109 again.
- Eliminate the short circuit between BU6/BU7 and apply a direct voltage of 1.2 ... 2 V.
The reading should have an accuracy of at least $\pm 0.2\%$ with respect to the input value.
- Adjust the reading with R101/R102 (coarse and fine) to the nominal value.
- Reverse the polarity of the input voltage and check the value at the reverse polarity.
If there is a deviation, pos. or neg. CAL. (see 2.2.).
- Apply an accurate direct voltage of 10...17 mV $\pm 0.05\%$ to BU6/BU7. (When the automatic range selector does not change over to the most sensitive range briefly interrupt the input voltage).
- When the reading does not exactly correspond to the nominal value, adjust with R340.
A deviation of $\pm$ one digit is permissible.
Important: When soldering on R340, wait at least 5 minutes before the check is repeated.

XII-4. High-ohmic voltage divider

- Depress buttons "DC/R and "V".
- Carry out zero adjustment with R2 (0 control).
- Apply a direct voltage of 10...17 V $\pm 0.02\%$ to BU6/7.
- Adjust to nominal value with R204.
- Check the reading at reversed polarity.

XII-5. Resistance ranges

5.1. Ω ranges

- Depress buttons "DC/R" and "V".
- Set the instrument to zero with R2 (0 control).
- Connect a measuring resistor of 1...2 $\Omega \pm 0.02\%$ (resistance decade) to BU2/BU3 and depress button Ω .
- Adjust the nominal value with R322.
- Check the 100 Ω and 10 Ω ranges by connecting corresponding resistors.

5.2. k Ω ranges

- Depress buttons "DC/R" and "k Ω ".
- Connect a measuring resistor of 100...190 k $\Omega \pm 0.1\%$ to BU2/BU3.
- Adjust R5 to nominal value with the aid of R11 (series or in parallel).

5.3. MΩ ranges

- Depress buttons "DC/R" and "MΩ"
- Connect a measuring resistor of $10\text{ M}\Omega \pm 0.2\%$ to BU2/BU3
- Adjust to nominal value with R12.

XII-6. Checking the range selection

6.1. Automatic range selection

- Depress buttons "DC/R" and "mV", set switch SK3 to "AUT"
- Short-circuit BU6 and BU7 and set the instrument to zero with R2 (0 control)
- Connect a variable voltage source to BU6/BU7
- Adjust the source to 20 mV (increase gradually from 0); the reading should be 17.99. Then slightly increase the voltage. The neg reading is e.g. 020.0.
- Slowly reduce the voltage again. At 18 mV the reading is still 018.0 and at a lower value the automatic range selector changes over to e.g. 17.99.
- Adjust the voltage to 199.0 mV. At a higher value changing over to e.g. 0200 will take place.
- Slowly reduce the voltage. At 0180 mV the reading will change from 0179 to e.g. 179.9 (Fig. 50).

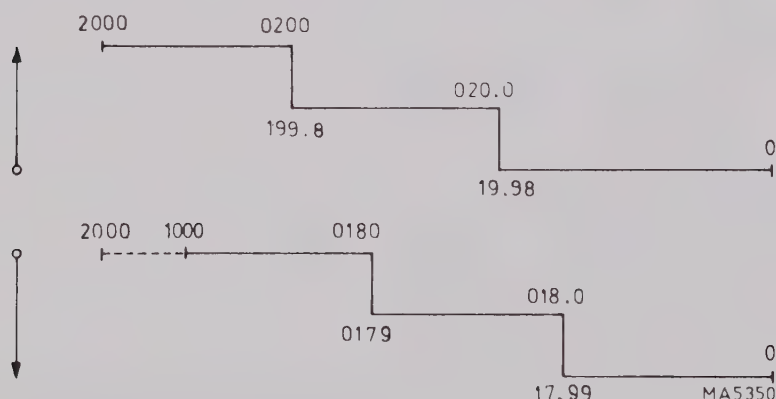


Fig. 49 Checking the range selection

6.2. Manual range selection

- Set the switch at the rear of the instrument to the ranges 1000, 100 and 10 by means of a screwdriver
- Check the position of the decimal point at the ranges:

1000 =	0000
100 =	000.0
10 =	00.00

XII-7. Checking the "OVERLOAD" indicator

- The instrument indicates a value of 1998 and the "OVERLOAD" lamp does not light up
- As soon as this value is exceeded with 1 digit i.e. at 2000, lamp "OVERLOAD" should light up.

XII-8. AC amplifier

8.1. Zero setting

- Depress buttons "AC" and "mV"
- Connect a d.c. voltmeter (e.g. another digital voltmeter) to analogue output BU9/BU10
- Short circuit capacitor C220 and connect this line to the circuit zero
- Adjust the d.c. output signal (test instrument) with R249 to zero ± 1 mV
- Disconnect the wire to the circuit zero, but leave C220 short-circuited
- Adjust the common mode suppression to zero ± 1 mV with R259
- Re-connect the short-circuit to the circuit zero and check again that the output voltage is 0 ± 1 mV. In case of a deviation repeat the adjustment.
- Remove the connection to the circuit zero and remove the short-circuit from C220.

8.2. Sensitivity adjustment

- Short-circuit BU6/BU7
- Observe the reading; this should run down to 0001 or 0002
- Apply a voltage of $1 \dots 1.7 V_{\text{rms}}$, 1 kHz $\pm 0.05\%$ to BU6/BU7
- Adjust the sensitivity to the nominal value with R242
- If this adjustment does not give the correct result, correct with R225 until the control range of R242 is approximately in the centre.

Caution: R225 should never be unsoldered when the instrument is switched on, and the instrument should not be switched on when R225 is disconnected. This would cause a chain reaction of defects!

8.3. Frequency response

- Apply a voltage of $1 \dots 1.7 V$, $\pm 0.05\%$, 1 MHz to BU6/BU7
- Adjust for nominal value with trimmer C210
- Adjust the frequency to 300 kHz and check the nominal value. If necessary, correct with C209 and re-check at 1 MHz (point 8.3. subpoint 1)
- When both adjustments are correct adjust the frequency to 600 kHz and check whether the reading corresponds to the nominal value. For correction, change the value of C212 and repeat the complete adjustment of point 8.3.

8.4. AC adjustment of the high-ohmic voltage divider

- Depress buttons "AC" and "V"
- Apply an alternating voltage of $10 \dots 17 V \pm 0.05\%$, $20 \dots 50$ Hz to BU6/BU7. The reading should correspond to the nominal value, otherwise the d.c. adjustment is not correct.
- Adjust the frequency to 50 kHz. Adjust for nominal value, + or -1 digit, with trimmer C202.
- Adjust the frequency to 1 MHz. Adjust for nominal value, + or -1 digit, with R205
- Adjust the frequency to 2 kHz. If the reading deviates more than + 4 digits from the nominal value, add R264 (carbon resistor $1.8 M\Omega$) and start at point 8.4. subpoint 3.
- Repeat the complete adjusting procedure 8.4 and readjust, if necessary, until the nominal value is attained throughout the frequency range.

8.5. Setting of TS207...TS209

- Measure the voltage on C214 with a DC milli-voltmeter.
Without drive signal the voltage should be $-3\text{ V} \pm 0.8\text{ V}$ with respect to the circuit zero.
If this voltage deviates, adjust with R228.
- If a considerable variation occurs (resistance variation $> 50\text{ ohms}$), adjusting procedures 8.2, 8.3 and 8.4 should be completely repeated.

XII-9. HF section

- Depress buttons "HF" and "mV"
- Connect the HF measuring probe (PM 9203) to BU1 and apply a voltage of $1.7\text{ V}_{\text{rms}} \pm 1\%$, 300 kHz to the probe via leads which are as short as possible (max. 5 cm).
- Adjust for nominal value with R337 (the alternating voltage may also be checked at the AC range of the PM 2421)
- Set potentiometer R1 (HF Adj.) to the mid position
- Apply a voltage of $2...5\text{ mV}_{\text{rms}} \pm 1\%$, 300 kHz to the probe
- Adjust for nominal value with R331
- Effect zero adjustment
- Depress buttons "AC" and "mV"
- Connect BU8 (300 kHz OUT) to BU7 via a connection cable
- Connect the HF measuring probe to BU7 and connect the earthing lead of the probe to BU6
- Read and note the measured value (take the reading after approx. 20 secs.)
- Depress button HF
- Adjust the instrument accurately to the noted reading with R1 (HF Adj.)
- Fix the arrow of R1 so that it points vertically upwards when the adjustment is correct.
Note: This adjustment only applies to the probe with which it has been carried out.
- Disconnect the probe from BU and remove the connection with BU8.

XII-10. Analogue output

- Depress buttons "DC/R" and "mV"
- Apply a variable direct voltage of $0...1.998\text{ V}$ to BU6/BU7
- Connect a second PM 2421 digital voltmeter to BU9/BU10
- The output voltage across BU9/BU10 is 3.5 mV per digit
Therefore, the output voltage will be 7 V at 2000 mV input voltage. Check at various input voltages.
- The polarity of the output voltage on BU10 (HI) is reversed with respect to the d.c. input voltage on BU7 (HI).

XIII. List of parts

XIII-1. MECHANICAL

Item	Fig.	Qty	Ordering number		Description
1	51	1	5322 134	20066	Indication lamp LA1
2	51	1	5322 277	10226	Mains switch SK1
3	51	1	5322 456	14011	Text plate
4	4+51	9	5322 290	40011	Socket BU2...BU10
5	51	2	5322 414	34052	Knob R1 + R2
6	51	2	5322 413	70067	Arrow for knob item 5
7	51	1	5322 267	44018	5 pole connection socket BU1
8	51	1	5322 276	84028	Push-button assembly SK2
9	51	1	5322 450	60068	Plexiglass window, red
10	51	1	5322 460	60025	Ornamental strip
11	52	1	5322 273	50099	Range selector SK3
12	52	1	5322 265	30066	Mains socket CS1
13	52	4	5322 462	40109	Rubber stud
14	53+54	14	5322 404	50375	Support for printed circuit board (for U1, U2, U3 and U4)
15	-	4	5322 693	40002	Support for printed circuit board (for U5)
16	-	5	5322 255	70145	Valve holder
17*	1A	5	5322 290	80213	Measuring cable, complete
18	-	1	5322 266	20015	Measuring probe 1:1
19	-	1	5322 268	10039	Measuring hook
20	-	1	5322 264	20016	Measuring clip
21	-	1	5322 321	20096	Earthing cable(15 cm)
22	-	1	5322 268	10029	Measuring pin
23	1B	1	5322 290	40077	Measuring terminal
24	-	1	5322 395	50085	Allen key 2.5 mm
25	-	1	5322 321	10071	Mains lead
26	-	1	4822 264	20006	Measuring clip, black
27	-	1	4822 264	20007	Measuring clip, red
28	53+54	2	4822 256	30056	Fuse holder VL1 and VL3
29	-	2	5322 417	54001	Locking-device
30	-	1	5322 321	20134	Earthing cable (30 cm)
31	-	2	5322 255	40089	Transistor holder
32	-	3	5322 255	40098	IC socket

*The measuring cable supplied is provided with two 4-mm plugs at the instruments side.

As replacement a cable with a BNC connector will be delivered. Adaption from BNC connector to 4-mm sockets is possible by means of an adapter 5322 263 50028.

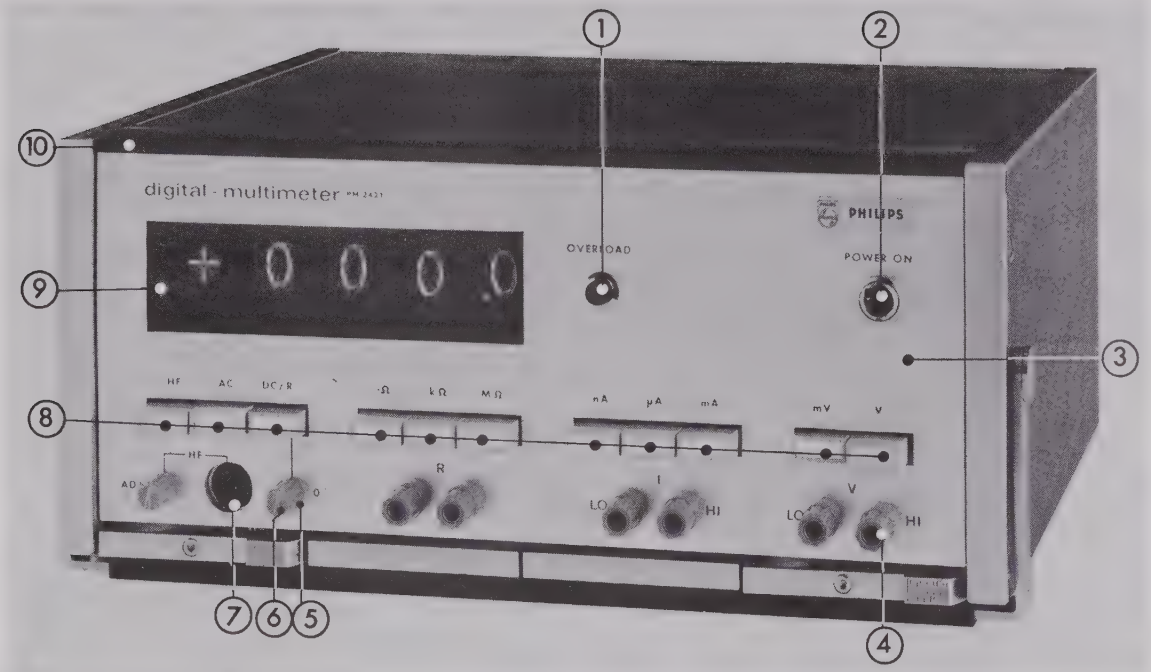


Fig. 50 Front view with item numbers

MA5351

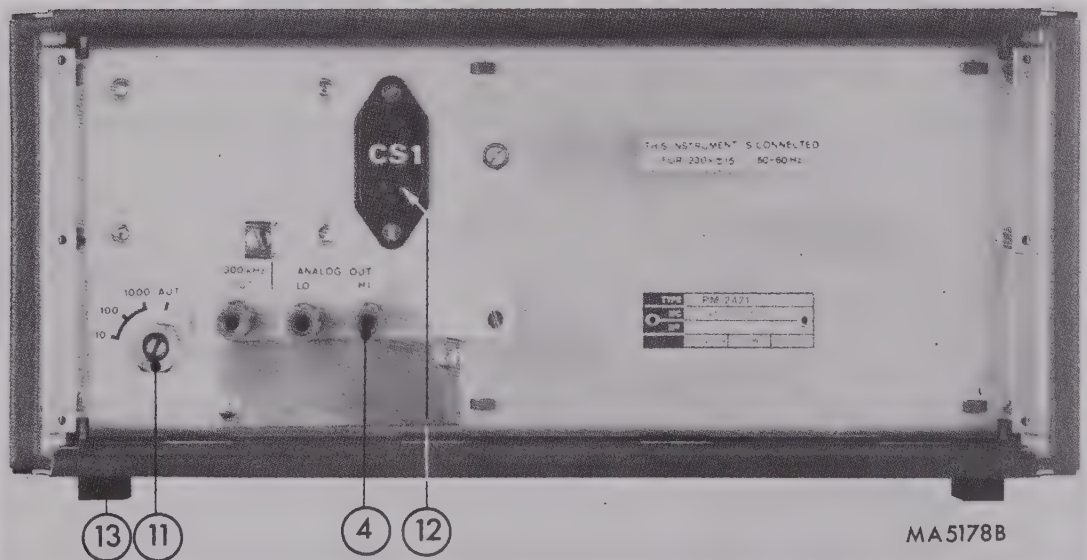


Fig. 51 Rear view with item numbers

MA5178B

B. ELECTRICAL — ELEKTRISCH — ELEKTRISCH — ELECTRIQUE — ELECTRICOS

This parts list does not contain multi-purpose and standard parts. These components are indicated in the circuit diagram by means of identification marks. The specification can be derived from the survey below.

Diese Ersatzteilliste enthält keine Universal- und Standard-Teile. Diese sind im jeweiligen Prinzipschaltbild mit Kennzeichnungen versehen. Die Spezifikation kann aus nachstehender Übersicht abgeleitet werden.

In deze stuklijst zijn geen universele en standaardonderdelen opgenomen. Deze componenten zijn in het prinsipschema met een merkteken aangegeven. De specificatie van deze merktekens is hieronder vermeld.

La présente liste ne contient pas des pièces universelles et standard. Celles-ci ont été repérées dans le schéma de principe. Leurs spécifications sont indiquées ci-dessous.

Esta lista de componentes no comprende componentes universales ni standard. Estos componentes están provistos en el esquema de principio de una marca. El significado de estas marcas se indica a continuación.

 Carbon resistor E24 series Kohleschichtwiderstand, Reihe E24 Koolweerstand E24 reeks Résistance au carbone, série E24 Resistencia de carbón, serie E24	$\left. \begin{array}{l} 0,125 \text{ W} \\ 5\% \end{array} \right\}$	 Carbon resistor E12 series Kohleschichtwiderstand, Reihe E12 Koolweerstand E12 reeks Résistance au carbone, série E12 Resistencia de carbón, serie E12	$\left. \begin{array}{l} 1 \text{ W} \leq 2,2 \text{ M}\Omega, 5\% \\ > 2,2 \text{ M}\Omega, 10\% \end{array} \right\}$
 Carbon resistor E12 series Kohleschichtwiderstand, Reihe E12 Koolweerstand E12 reeks Résistance au carbone, série E12 Resistencia de carbón, serie E12	$\left. \begin{array}{l} 0,25 \text{ W} \leq 1 \text{ M}\Omega, 5\% \\ > 1 \text{ M}\Omega, 10\% \end{array} \right\}$	 Carbon resistor E12 series Kohleschichtwiderstand, Reihe E12 Koolweerstand E12 reeks Résistance au carbone, série E12 Resistencia de carbón, serie E12	$\left. \begin{array}{l} 2 \text{ W} \\ 5\% \end{array} \right\}$
 Carbon resistor E24 series Kohleschichtwiderstand, Reihe E24 Koolweerstand E24 reeks Résistance au carbone, série E24 Resistencia de carbón, serie E24	$\left. \begin{array}{l} 0,5 \text{ W} \leq 5 \text{ M}\Omega, 1\% \\ > 5 \text{ M}\Omega, 2\% \\ > 10 \text{ M}\Omega, 5\% \end{array} \right\}$	 Wire-wound resistor Drahtwiderstand Draadgewonden weerstand Résistance bobinée Resistencia bobinada	$\left. \begin{array}{l} 0,4 - 1,8 \text{ W} \\ 0,5\% \end{array} \right\}$
 Carbon resistor E12 series Kohleschichtwiderstand, Reihe E12 Koolweerstand E12 reeks Résistance au carbone, série E12 Resistencia de carbón, serie E12	$\left. \begin{array}{l} 0,5 \text{ W} \leq 1,5 \text{ M}\Omega, 5\% \\ > 1,5 \text{ M}\Omega, 10\% \end{array} \right\}$	 Wire-wound resistor Drahtwiderstand Draadgewonden weerstand Résistance bobinée Resistencia bobinada	$\left. \begin{array}{l} 5,5 \text{ W} \leq 200 \Omega, 10\% \\ > 200 \Omega, 5\% \end{array} \right\}$
 Wire-wound resistor Drahtwiderstand Draadgewonden weerstand Résistance bobinée Resistencia bobinada	$\left. \begin{array}{l} 10 \text{ W} \\ 5\% \end{array} \right\}$		
 Tubular ceramic capacitor Rohrkondensator Keramische kondensator, buistype Condensateur céramique tubulaire Condensador cerámico tubular	$\left. \begin{array}{l} 500 \text{ V} \end{array} \right\}$	 Polyester capacitor Polyesterkondensator Polyesterkondensator Condensateur au polyester Condensador polyester	$\left. \begin{array}{l} 400 \text{ V} \end{array} \right\}$
 Tubular ceramic capacitor Rohrkondensator Keramische kondensator, buistype Condensateur céramique tubulaire Condensador cerámico tubular	$\left. \begin{array}{l} 700 \text{ V} \end{array} \right\}$	 Flat-foil polyester capacitor Miniatur-Polyesterkondensator (flach) Platte miniatuur polyesterkondensator Condensateur au polyester, type plat Condensador polyester, tipo de placas planas	$\left. \begin{array}{l} 250 \text{ V} \end{array} \right\}$
 Ceramic capacitor, "pin-up" Keramikkondensator "Pin-up" (Perltyp) Keramische kondensator "Pin-up" type Condensateur céramique, type perle Condensador cerámico, versión "colgable"	$\left. \begin{array}{l} 500 \text{ V} \end{array} \right\}$	 Paper capacitor Papierkondensator Papierkondensator Condensateur au papier Condensador de papel	$\left. \begin{array}{l} 1000 \text{ V} \end{array} \right\}$
 "Microplate" ceramic capacitor Miniatur-Scheibenkondensator "Microplate" keramische kondensator Condensateur céramique "microplate" Condensador cerámico "microplaca"	$\left. \begin{array}{l} 30 \text{ V} \end{array} \right\}$	 Wire-wound trimmer Drahttrimmer Draadgewonden trimmer Trimmer à fil Trimmer bobinado	
 Mica capacitor Glimmerkondensator Micakondensator Condensateur au mica Condensador de mica	$\left. \begin{array}{l} 500 \text{ V} \end{array} \right\}$	 Tubular ceramic trimmer Rohrtrimmer Buisvormige keramische trimmer Trimmer céramique tubulaire Trimmer cerámico tubular	



For multi-purpose and standard parts, please see PHILIPS' Service Catalogue.

Für die Universal- und Standard-Teile siehe den PHILIPS Service-Katalog.

Voor universele en standaardonderdelen raadplege men de PHILIPS Service Catalogus.

Pour les pièces universelles et standard veuillez consulter le Catalogue Service PHILIPS.

Para piezas universales y standard consulte el Catálogo de Servicio PHILIPS.

Resistors

No.	Ordering number			Value	%	W	Description
R 1	5322	101	20323	47 k Ω			Potentiometer
R 2	5322	101	20242	100 k Ω			Potentiometer
R 3	5322	116	50737	988 k Ω	0.25	0.25	Metal film
R 4	5322	116	50737	988 k Ω	0.25	0.25	Metal film
R 5	5322	116	50101	2 k Ω	0.25	0.125	Metal film
R 6	5322	116	50424	1 k Ω	0.25	0.25	Metal film
R 9	5322	113	24091	6.98 Ω	0.5	0.4	Wire wound
R 10	5322	113	10166	1 Ω	0.25	0.4	Wire wound
R 12	5322	101	14048	47 k Ω			Potentiometer
R103	5322	116	54778	237 k Ω	0.5	0.125	Metal film
R104	5322	116	51023	249 k Ω	0.5	0.125	Metal film
R105	5322	116	51023	249 k Ω	0.5	0.125	Metal film
R106	5322	116	51023	249 k Ω	0.5	0.125	Metal film
R107	4822	116	50244	100 k Ω	1	0.125	Metal film
R109	5322	100	10036	4.7 k Ω			Potentiometer
R136	5322	116	54759	464 k Ω	1	0.25	Metal film
R138	5322	116	54426	121 Ω	1	0.125	Metal film
R141	5322	116	50557	46.4 k Ω	1	0.125	Metal film
R142	5322	116	50557	46.4 k Ω	1	0.125	Metal film
R145	5322	116	54426	121 Ω	1	0.125	Metal film
R149	5322	116	54334	3.5 M Ω	0.5	1	Pyro film
R201	5322	116	50736	10 M Ω	0.5		Metal film
R202	5322	116	50463	10 k Ω	0.25	0.125	Metal film
R203	5322	116	50578	78.7 Ω	1	0.125	Metal film
R204	5322	100	10075	100 Ω	20	0.15	Carbon potentiometer
R207	5322	116	50022	1 M Ω	1	0.25	Metal film
R208	5322	116	50579	3.16 k Ω	1	0.125	Metal film
R209	5322	116	50096	562 Ω	1	0.125	Metal film
R211	5322	116	50581	2.49 k Ω	1	0.125	Metal film
R219	5322	116	50458	7.87 k Ω	1	0.125	Metal film
R220	5322	116	50753	154 Ω	1	0.125	Metal film
R221	5322	116	50753	154 Ω	1	0.125	Metal film
R222	5322	116	50583	5.9 k Ω	1	0.125	Metal film
R224	5322	116	50584	619 Ω	0.5	0.25	Metal film
R229	5322	116	51056	11 k Ω	0.5	0.25	Metal film
R230	5322	116	50484	4.64 k Ω	1	0.125	Metal film
R233	5322	116	50585	162 Ω	0.5	0.25	Metal film
R239	5322	116	50586	1.54 k Ω	1	0.125	Metal film
R241	5322	112	10107	1 k Ω	0.25	0.4	Wire wound
R242	5322	103	10122	10 Ω		2	Wire wound potentiometer
R243	5322	116	50104	6.81 k Ω	1	0.125	Metal film
R245	5322	116	50104	6.81 k Ω	1	0.125	Metal film
R246	5322	116	50104	6.81 k Ω	1	0.125	Metal film

No.	Ordering number			Value	%	W	Description
R247	5322	116	50104	6.81 kΩ	1	0.125	Metal film
R249	4822	101	10022	100 kΩ	20	0.15	Carbon potentiometer
R255	5322	112	10257	500 Ω	0.5	0.4	Wire wound
R256	5322	112	10257	500 Ω	0.5	0.4	Wire wound
R257	5322	112	10257	500 Ω	0.5	0.4	Wire wound
R258	5322	112	10257	500 Ω	0.5	0.4	Wire wound
R259	5322	103	10074	50 Ω		2	Wire wound potentiometer
R260	5322	113	24092	6.98 kΩ	0.25	0.7	Metal film
R261	5322	113	24092	6.98 kΩ	0.25	0.7	Metal film
R263	5322	116	50587	4.99 kΩ	0.25	0.125	Metal film
R321	5322	113	40143	12.1 kΩ	0.5	0.7	Wire wound
R322	5322	103	10121	220 Ω	10	2	Wire wound potentiometer
R323	5322	113	40144	6.19 kΩ	0.5	0.6	Wire wound
R324	5322	116	50557	46.4 kΩ	1	0.125	Metal film
R325	5322	116	50441	178 kΩ	1	0.125	Metal film
R328	5322	113	40145	5.11 kΩ	0.5	0.6	Wire wound
R331	4822	101	10027	47 kΩ	20	0.15	Carbon potentiometer
R335	4822	111	50323	100 MΩ	10	1	Carbon
R337	5322	101	10022	100 kΩ	20	0.25	Carbon potentiometer
R341	5322	116	50274	1 kΩ	0.1		Metal film
R342	5322	116	50268	100 Ω	0.1		Metal film
R343	5322	113	40146	11.3 Ω	0.5		Wire wound
R401	5322	116	54164	71.5 kΩ	0.5	0.1	Metal film
R402	5322	103	10121	220 Ω	10	2	Wire wound potentiometer
R403	5322	116	54152	21.5 kΩ	0.5	0.1	Metal film
R404	5322	116	54164	71.5 kΩ	0.5	0.1	Metal film
R405	5322	103	10121	220 Ω	10	2	Wire wound potentiometer
R406	5322	116	54152	21.5 kΩ	0.5	0.1	Metal film
R409	5322	116	50362	53.6 kΩ	0.5	0.1	Metal film
R410	5322	116	50427	32.4 kΩ	0.5	0.1	Metal film
R411	5322	116	50427	32.4 kΩ	0.5	0.1	Metal film
R412	5322	116	50361	17.8 kΩ	0.5	0.1	Metal film
R413	5322	116	50361	17.8 kΩ	0.5	0.1	Metal film
R414	5322	116	50361	17.8 kΩ	0.5	0.1	Metal film
R415	5322	116	50268	100 Ω	1	0.125	Metal film
R416	5322	116	50268	100 Ω	1	0.125	Metal film
R417	5322	116	50484	4.64 kΩ	1	0.125	Metal film
R418	5322	103	10121	220 Ω	10	2	Wire wound potentiometer
R419	5322	116	50484	4.64 kΩ	1	0.125	Metal film
R420	5322	116	50538	3.32 kΩ	1	0.125	Metal film
R421	5322	116	50591	7.87 kΩ	0.5	0.1	Metal film
R422	5322	116	50159	51.1 Ω	1	0.125	Metal film
R457	5322	116	50158	5.11 kΩ	1	0.125	Metal film
R458	5322	116	50525	14.7 kΩ	1	0.125	Metal film
R461	5322	116	50592	442 Ω	1	0.125	Metal film

No.	Ordering number			Value		%	W	Description
R462	5322	116	50274	1	kΩ	1	0.125	Metal film
R512	5322	116	51056	11	kΩ	1	0.125	Metal film
R513	5322	116	51056	11	kΩ	1	0.125	Metal film
R514	5322	116	50729	4.22	kΩ	1	0.125	Metal film
R526	5322	113	10141	2.49	kΩ	0.5	0.4	Wire wound
R527	5322	113	10142	1.96	kΩ	0.5	0.4	Wire wound
R530	5322	113	10113	1.69	kΩ	0.5	0.4	Wire wound
R531	5322	113	10142	1.96	kΩ	0.5	0.4	Wire wound
R532	4822	116	60005	1	Ω	10	0.125	Carbon
R533	4822	116	60005	1	Ω	10	0.125	Carbon
R534	5322	113	60085	1	Ω	10	1	Wire wound
R535	5322	112	10027	1	Ω	1	0.4	Wire wound
R536	4822	116	60005	1	Ω	10	0.125	Carbon
R540	5322	116	50593	16.2	kΩ	1	0.125	Metal film
R541	5322	116	50463	10	kΩ	1	0.125	Metal film

Capacitors

No.	Ordering number			Value		%	V	Description
C 2	4822	121	50058	510	pF	5	125	Polystyrene
C 3	4822	120	10109	1200	pF	20	500	Ceramic
C101	5322	121	40231	0.15	μF	10	100	Polycarbonate
C102	4822	121	40231	150	nF	10	100	Polycarbonate
C103	4822	121	40231	150	nF	10	100	Polycarbonate
C104	4822	121	40323	100	nF	10	100	Polycarbonate
C105	4822	121	50424	1	nF	1	63	Polycarbonate
C106	5322	121	40256	2,2	nF	10	100	Polycarbonate
C107	4822	121	30128	4.7	nF	10	100	Polycarbonate
C108	4822	121	40232	220	nF	10	100	Polycarbonate
C109	5322	121	40323	100	nF	10	100	Polycarbonate
C110	4822	121	40231	150	nF	10	100	Polycarbonate
C111	4822	124	20395	220	μF		16	Electrolytic
C112	4822	124	20395	220	μF		16	Electrolytic
C113	4822	124	20405	470	μF		6.3	Electrolytic
C114	5322	121	54018	10	nF	1	63	Polycarbonate
C115	5322	121	54018	10	nF	1	63	Polycarbonate
C116	5322	121	44002	10	nF	10	250	Polycarbonate
C202	5322	125	50044	6.4	pF	20	500	Trimmer
C203	4822	121	50229	18	nF	1	63	Polystyrene
C204	5322	121	40246	0.27	μF	10	400	Polycarbonate
C205	5322	121	40197	1	μF	10	100	Polycarbonate
C207	4822	124	20402	330	μF		6.4	Electrolytic
C210	5322	125	50044	6.4	pF	20	500	Trimmer

No.	Ordering number			Value		%	V	Description
C214	4822	124	20365	32	μF		10	Electrolytic
C215	4822	121	40059	0.1	μF	10	100	Polycarbonate
C216	5322	121	50097	10	nF	1	63	Polystyrene
C217	5322	124	20382	100	μF		10	Electrolytic
C218	5322	124	20382	100	μF		10	Electrolytic
C219	5322	121	40232	220	nF	10	100	Polycarbonate
C220	5322	121	40224	4.7	μF	10	100	Polycarbonate
C221	5322	121	40224	4.7	μF	10	100	Polycarbonate
C222	5322	121	40197	1	μF	10	100	Polycarbonate
C223	4822	124	20377	64	μF		16	Electrolytic
C224	4822	121	50079	2	nF	5	63	Polystyrene
C225	4822	121	50079	2	nF	5	63	Polystyrene
C226	5322	121	40232	220	nF	10	100	Polycarbonate
C229	4822	124	20356	12.5	μF		25	Electrolytic
C230	4822	124	20356	12.5	μF		25	Electrolytic
C231	5322	121	40197	1	μF	10	100	Polycarbonate
C301	4822	121	40047	0.01	μF	10	250	Polycarbonate
C302	5322	121	40323	0.10	μF	10	100	Polycarbonate
C303	5322	121	50438	1.2	nF	5	63	Polystyrene
C304	5322	121	40175	0.47	μF	10	100	Polycarbonate
C305	5322	121	40175	0.47	μF	10	100	Polycarbonate
C306	5322	121	50415	2.2	nF	5	63	Polystyrene
C307	4822	124	20353	10	μF		16	Electrolytic
C308	4822	124	20353	10	μF		16	Electrolytic
C310	4822	121	40047	0.01	μF	10	250	Polycarbonate
C311	5322	121	40175	0.47	μF	10	100	Polycarbonate
C313	4822	121	50414	3	nF	5	63	Polystyrene
C314	5322	121	40197	1	μF	10	100	Polycarbonate
C315	5322	124	10067	8.2	μF		16	Electrolytic
C402 [*]	5322	121	44077	1	μF	10	100	Polystyrene
C407	4822	124	20364	33	μF		6.3	Electrolytic
C414	4822	124	20358	15	μF		16	Electrolytic
C418	4822	121	50234	6800	pF	1	63	Polystyrene
C419	4822	124	20349	6.8	μF		10	Electrolytic
C501	5322	124	20037	16	μF		400	Electrolytic
C502	4822	121	40239	47	nF		400	Polycarbonate
C503	5322	124	10004	10	μF		25	Electrolytic
C504	5322	124	20407	470	μF		40	Electrolytic
C505	5322	124	10004	10	μF		25	Electrolytic
C506	5322	124	20407	470	μF		40	Electrolytic
C512	5322	124	10004	10	μF		25	Electrolytic
C513	5322	124	10004	10	μF		25	Electrolytic
C514	4822	124	70085	800	μF		16	Electrolytic
C518	5322	121	40256	2.2	μF	10	100	Polycarbonate

^{*} See VIII-6.

Miscellaneous

No.	Ordering number			Description
T1	5322	146	34037	Mains transformer
VL1	5322	253	30009	Fuse 160 mA, delayed action (220 V mains)
VL1	5322	253	30013	Fuse 250 mA, delayed action (110 V mains)
VL2	5322	252	20001	Thermal fuse 125°C
VL3	5322	253	20022	Fuse 1.6 A
U1	5322	216	94084	Printed circuit board, complete
U2*	5322	216	20149	Printed circuit board, complete
U3	5322	216	20151	Printed circuit board, complete
U4	5322	216	74029	Printed circuit board, complete (without indicators)
U5	5322	216	20153	Printed circuit board, complete
B101	5322	134	20102	Neon lamp GL6
TR101	5322	693	94012	Photo-chopper
L201	5322	158	10275	Coil 3.3 μ H
L202	5322	158	10276	Coil 4.7 μ H
L203	5322	158	10277	Coil 470 μ H
L204	5322	158	10278	Coil 1 mH
IC201	5322	209	84112	Operational amplifier TBA221
L301	5322	158	50032	Oscillator transformer
RE301	5322	280	20039	Reed relay
RE302	5322	280	20039	Reed relay
RE303	5322	280	20039	Reed relay
IC101	5322	209	84371	Operational amplifier TBA231
IC401	5322	209	80232	BCD - to - decimal decoder/driver N7441N Signatics (replacement for N74141B)
IC402	5322	209	80232	
IC403	5322	209	80232	
IC404	5322	209	80059	Quadruple bistable latch FJJ181 (or Texas Instruments SN7475N)
IC405	5322	209	80059	
IC406	5322	209	80059	
IC407	5322	209	84114	Decade counter FJJ141 (or Texas Instruments SN7490N)
IC408	5322	209	84114	
IC409	5322	209	84114	
IC410	5322	209	80108	Dual J-K master-slave flip-flop FJJ121 (or Texas Instruments SN7473N)
IC411	5322	209	80106	8-Input Nand gate FJH101 (or Texas Instruments SN7430N)
IC412	5322	209	80106	
IC413	5322	209	80023	Quadruple 2-input Nand-gate FJH131 (or Texas Instruments SN7400N)
IC414	5322	209	80023	
IC415	5322	209	80107	J-K master-slave flip-flop FJJ111 (or Texas Instruments SN7472N)
IC416	5322	209	80108	Dual J-K master-slave flip-flop FJJ121 (or Texas Instruments SN7473N)

*Replace R260 and R261 by components with the values given in the parts list.

No.	Ordering number			Description
IC417	5322	209	80023	Quadruple 2-input Nand-gate FJH131 (or Texas Instruments SN7400N)
IC418	5322	209	80062	Triple 3-input Nand-gate FJH121 (or Texas Instruments SN7410N)
IC419	5322	209	80023	Quadruple 2-input Nand-gate FJH131 (or Texas Instruments SN7400N)
IC420	5322	209	80023	
IC421	5322	209	80024	Dual 4-input Nand-gate FJH111
IC422	5322	209	80065	Dual D-type edge-triggered flip-flop FJJ131 (or Texas Instruments SN7474N)
IC423	5322	209	80023	Quadruple 2-input Nand-gate FJH131 (or Texas Instruments SN7400N)
IC424	5322	209	84112	Operational amplifier TBA221
IC425	5322	209	80081	Comparator RC710 (Raytheon), (or Texas Instruments SN72710L)
B401	5322	131	90031	Indicator ZM 1000
B402				Indicator ZM 1000
B403				Indicator ZM 1000
B404				Indicator ZM 1000
B405	5322	131	90038	Indicator ZM 1000

Transistors

TS1	5322	130	40503	MJE340 (Motorola)	TS207	5322	130	40326	BF173
TS2	5322	130		BD201	TS208	5322	130	40369	BC179B
TS101	5322	130	40408	BFW13	TS209	5322	130	40369	BC179B
TS102	5322	130	40408	BFW13	TS210	5322	130	40369	BC179B
TS103	5322	130	44041	BSU81	TS211	5322	130	40369	BC179B
TS104	5322	130	40709	BFS21A	TS212	5322	130	40369	BC179B
TS105	5322	130	40357	BC107	TS213	5322	130	40423	BCY87
TS106	5322	130	40357	BC107	TS214	5322	130	40369	BC179B
TS107	5322	130	40522	BC177	TS215	5322	130	40369	BC179B
TS108	5322	130	40357	BC107	TS301	5322	130	40369	BC179B
TS109	5322	130	40357	BC107	TS302	5322	130	40369	BC179B
TS110	5322	130	40357	BC107	TS303	5322	130	40332	BC107B
TS111	5322	130	40357	BC107	TS304	5322	130	40332	BC107B
TS112	5322	130	40522	BC177	TS305	5322	130	40332	BC107B
TS201	5322	130	40408	BFW11 FET	TS306	5322	130	30187	BCY88
TS202	5322	130	40369	BC179B	TS307	5322	130	40144	BC109C
TS203	5322	130	40369	BC179B	TS308	5322	130	40144	BC109C
TS204	5322	130	40423	BCY87	TS309	5322	130	40144	BC109C
TS205	5322	130	40369	BC179B	TS401	5322	130	40505	BFY52*
TS206	5322	130	40369	BC179B	TS402	5322	130	40506	BFY52**

* See VIII-4.a

** See VIII-4.b

TS403	5322	130	40506	BFY52*	TS418	5322	130	40321	BSX21
TS404	5322	130	40332	BC107B	TS419	5322	130	40321	BSX21
TS405	5322	130	40369	BC179B	TS420	5322	130	40321	BSX21
TS406	5322	130	40369	BC179B	TS501	5322	130	40356	BFY51
TS407	5322	130	40369	BC179B	TS502	5322	130	40354	BC177
TS408	5322	130	40321	BSX21	TS503	5322	130	40356	BFY51
TS409	5322	130	40321	BSX21	TS504	5322	130	40332	BC107B
TS410	5322	130	40321	BSX21	TS505	5322	130	40144	BC109C
TS411	5322	130	40321	BSX21	TS506	5322	130	30187	BCY88
TS412	5322	130	40321	BSX21	TS507	5322	130	40369	BC179B
TS413	5322	130	40369	BC179B	TS508	5322	130	40369	BC179B
TS414	5322	130	40332	BC107B	TS509	5322	130	40369	BC179B
TS415	5322	130	40332	BC107B	TS510	5322	130	40369	BC179B
TS416	5322	130	40332	BC107B	TS511	5322	130	40144	BC109C
TS417	5322	130	40321	BSX21					

Diodes

GR1	5322	130	30273	BAX16	GR306	5322	130	30273	BAX16
GR101	5322	130	34037	BAV45	GR401	5322	130	40182	BAX13
GR102	5322	130	34037	BAV45	GR402	5322	130	40182	BAX13
GR103	5322	130	30087	AAY21	GR403	5322	130	40182	BAX13
GR104	5322	130	30613	BAW62	GR404	5322	130	40182	BAX13
GR105	5322	130	30613	BAW62	GR405	5322	130	40182	BAX13
GR106	5322	130	30613	BAW62	GR406	5322	130	34069	BZX79/C12 Zener
GR109	5322	130	30613	BAW62	GR407	5322	130	30766	BZX79/C6V2 Zener
GR110	5322	130	30613	BAW62	GR408	5322	130	40182	BAX13
GR111	5322	130	30613	BAW62	GR409	5322	130	40182	BAX13
GR112	5322	130	30613	BAW62	GR410	5322	130	40182	BAX13
GR113	5322	130	30773	BZX79/C4V7	GR411	5322	130	40182	BAX13
GR201	5322	130	30613	BAW62	GR412	5322	130	40182	BAX13
GR202	5322	130	30613	BAW62	GR413	5322	130	40182	BAX13
GR203	5322	130	30613	BAW62	GR414	5322	130	40182	BAX13
GR204	5322	130	30613	BAW62	GR415	5322	130	40182	BAX13
GR205	5322	130	30666	BZX79/C7V5 Zener	GR416	5322	130	30267	BZZ14 Zener
GR206	5322	130	30613	BAW62	GR417	5322	130	40182	BAX13
GR207	5322	130	30666	BZX79/C7V5 Zener	GR418	5322	130	40182	BAX13
GR208	5322	130	30323	IN4009	GR419	5322	130	40182	BAX13
GR209	5322	130	30084	AAZ18	GR420	5322	130	40182	BAX13
GR210	5322	130	30323	IN4009	GR421	5322	130	40182	BAX13
GR211	5322	130	40182	BAX13	GR422	5322	130	40182	BAX13
GR212	5322	130	40182	BAX13	GR423	5322	130	40182	BAX13
GR213	5322	130	40182	BAX13	GR424	5322	130	40182	BAX13
GR301	5322	130	40182	BAX13	GR425	5322	130	40182	BAX13
GR302	5322	130	40182	BAX13	GR426	5322	130	40182	BAX13
GR303	5322	130	40182	BAX13	GR427	5322	130	30229	AAZ15
GR304	5322	130	30273	BAX16	GR428	5322	130	30229	AAZ15
GR305	5322	130	30273	BAX16	GR429	5322	130	30229	AAZ15

*See VIII-4.b.

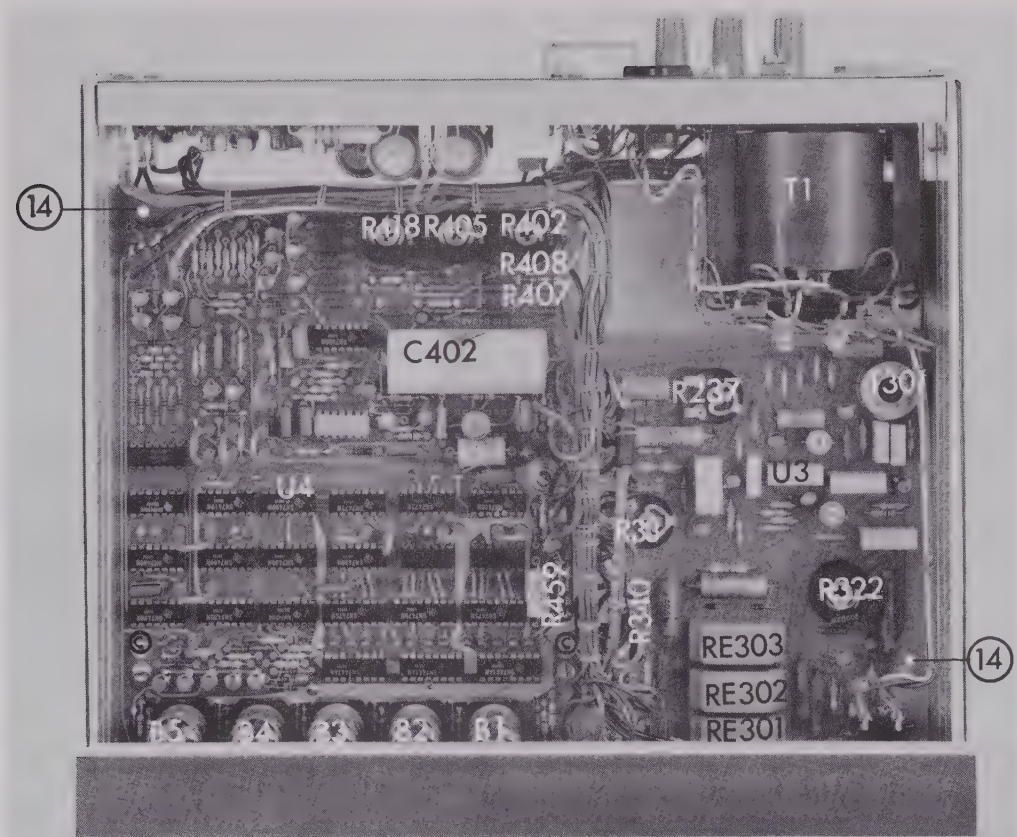


Fig. 53 Top view (chassis removed)

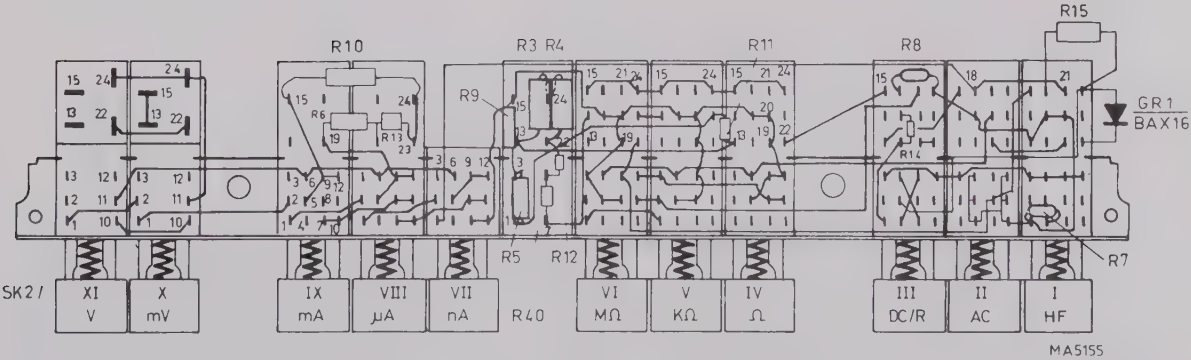


Fig. 54 Push button assembly SK2

XIV. HF probe PM 9203 and HF T-piece PM 9253

APPLICATION

HF Probe PM 9203 is suitable for measuring H.F. voltages from 2 mV up to 2 V in combination with digital multimeter PM 2421. For voltages from 2 V up to 200 V a capacitive voltage attenuator with a division ratio of 100: 1 is provided.

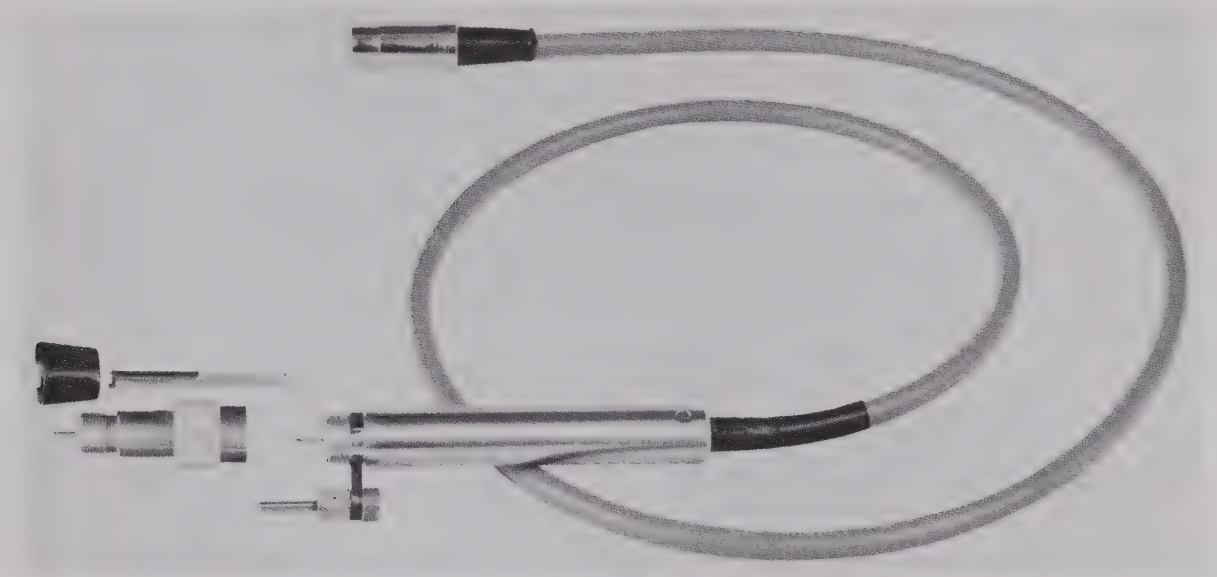


Fig. 55 HF-probe PM 9203 with capacitive voltage attenuator

TECHNICAL DATA

Probe PM 9203

Frequency response	300 kHz ... 700 MHz
Input capacitance	≤ 2 pF
Parallel damping resistance	10 k Ω ...200 k Ω , depending on voltage and frequency
Accuracy	see graph, Fig. 58
Accuracy of the capacitive attenuator 100:1	0.5 dB additional

HF - T - Piece PM 9253

Frequency response	300 kHz ... 1200 MHz
Impedance	50 Ω
Accuracy	$< + 5$ dB $< - 0$ dB
Standing-wave ration	see graph, Fig. 59



Fig. 56 T-piece PM 9253

Principle

Measurement of HF voltages is based on the compensation principle.
The HF measurement is described in detail in chapter IV-2.3.

Components of the probe

The electrical parts of the measuring probe are located on a small printed circuit board to which the probe tip is also fixed.

In the case of damage to or defects in these parts the complete printed circuit unit should be replaced.

The diodes have been selected as regards certain properties; therefore they should not be replaced individually. It is urgently disadvised to solder in the circuitry, as thermal effects may impair the properties of the circuit elements.

Therefore, it is only permitted to solder on the connection cable.

The connection cable of the measuring probe is of a special type and should not be replaced by a substitute.

Replacing the printed circuit board in the probe.

- Slightly cut out the transparent insulation sleeve at the place of the screw
- Remove the screw
- The casing can be readily slid off the probe
- Carefully unsolder the connection wires and mark them
- Remove the two small screws with which the printed circuit board is fixed in the holder
- Pull the printed circuit board carefully out in backward direction
- Fit the new printed wiring board, solder the cable in place and refit the casing.

Components of the attenuator 100:1 (see fig. 60)

The attenuator may be disassembled as follows:

- Unscrew nut (1)
- Remove the insulating disc (3)
- Remove the press-disc (2)
- Press the complete inner part (4), with insulating piece (6) and probe -tip (8) out of body (5).
This is possible by pressing a suitable sleeve over tip (8) against the adjustable nut(7).
- Remove adjusting nut (7) by means of the special key, supplied for this purpose
- Now it is possible to press the tip out of the insulating piece.

Adjustment of the attenuator 100:1

- Switch on instrument PM 2421
- Depress buttons "AC" and "V"
- Connect a sine wave generator to BU6/BU7
- Adjust the frequency of the generator to 300 kHz and the output voltage to 10 V exactly
- Screw the attenuator on the calibrated probe PM 9203 (For calibration see chapter VI-9)
- Connect the probe to the instrument PM 2421
- Connect the probe to the voltage of 10 V
- Depress buttons "HF" and "mV"
- The instrument should indicated 100 mV. If necessary, deviations can be corrected by means of the special key, supplied for this purpose. This may be carried out by turning the adjusting nut (7). The ratio of attenuation becomes larger if the nut is turned anticlockwise and becomes smaller in turning clockwise.
- Adjusting the attenuator is only possible in combination with probe PM 9203. An adjusted attenuator is therefore only to be used with that individual probe, with which the adjustment has been effected. If several probes and attenuators are available it is recommended to label the parts belonging together.
- At delivery from the factory the attenuator is adjusted with the probe.

List of components PM 9203

Qty.	Ordering number			Description
1	5322	216	70129	Printed circuit board, with measuring pin and components
1	5322	264	20022	Earthing clip
1	5322	492	61545	Earthing pin
1	5322	322	30005	Cable
1	4822	264	40023	5-pole plug

List of components PM 9253

1	5322	265	10014	Plug
1	5322	267	10042	Connector
1	5322	268	20045	Interconnection piece (between plug and connector)
1	5322	268	20046	Contact pin
1	5322	532	50803	Contact disc.

List of components attenuator

Fig.	Item	Qty.	Ordering number		Description
60	6	1	5322	532 60524	Insulating piece
60	7	1	5322	505 10486	Nut
60	8	1	5322	264 20026	Probe tip
60	9	1	5322	462 40264	Cap
56	-	1	5322	395 50114	Key
60	-	1	5322	210 70059	Attenuator 100:1, complete

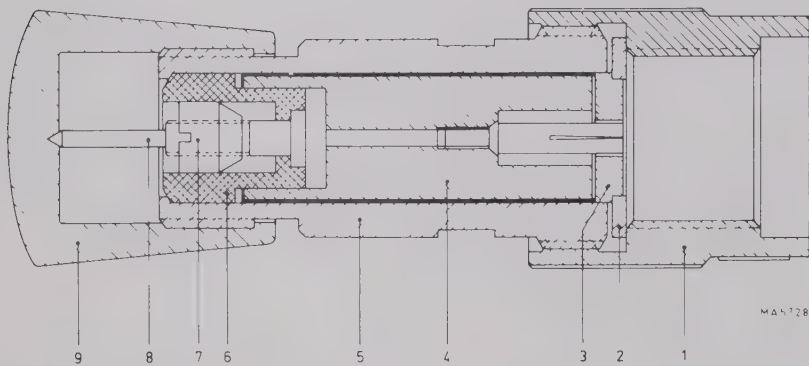


Fig. 59 Capacitive voltage attenuator

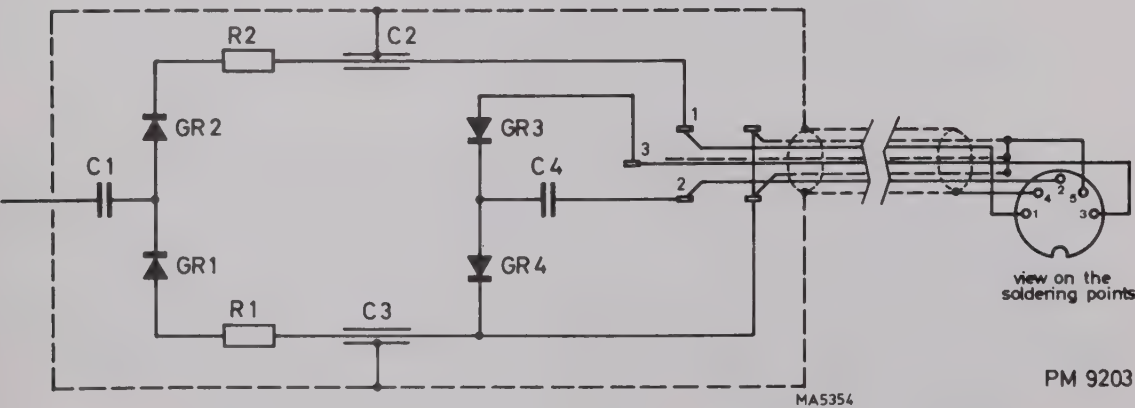


Fig. 60 Circuit diagram of probe PM 9203

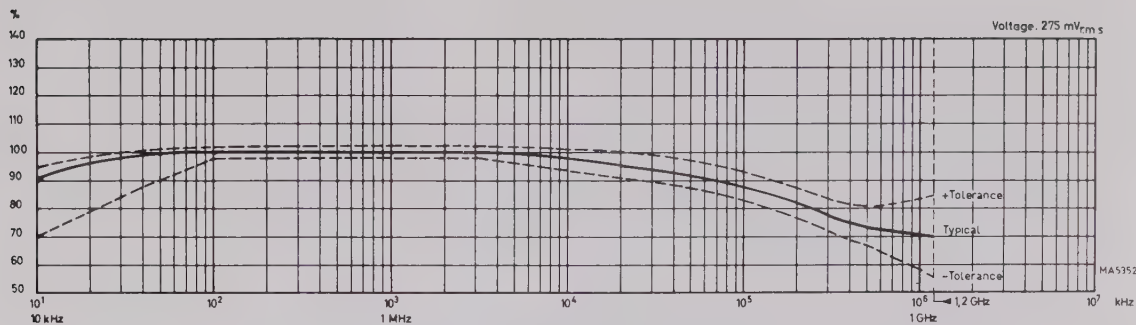


Fig. 57 Accuracy-curve of PM 9203 with PM 9253

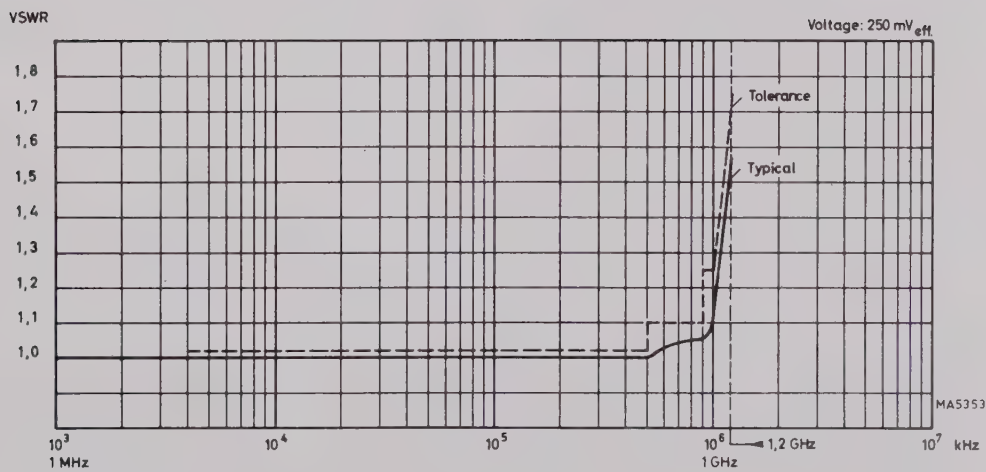


Fig. 58 Standing wave ratio of PM 9253

XV. Digital output unit PM 9221

INTRODUCTION

By means of this unit (separately available) instrument PM 2421 can be provided with a digital output. The information as regards result, polarity, range, overload, AC/DC, the transfer signal and the stop signal is taken from the memory and the other circuits via 20 isolation amplifiers and is transferred to the output.

The isolation amplifiers ensure feedback-free connection of the outputs to the instrument, so that the measuring result will not be affected.

The digital output may be used for controlling a printer, a parallel-series converter, limit selector, go/no-go test equipment, digital-to-analogue converter etc.

However, it should be taken into account that this output is galvanically coupled to the "LO" socket of the measuring inputs.

When the digital output is used the automatic range selector should be switched off in certain cases. However, it is sometimes also possible to suppress undesired signals which may occur after change-over to another range by means of an external circuit.

Technical data

Output/Input		Output contact at CS2 (rear of PM 2421) and at U6 (PM 9221)				1 $\triangle$ > 8 V/400 μ A 0 $\triangle$ < + 0.4 V/8 mA		
		A	B	C	D			
Result	"1"	1	2	3	4	13 BIT, from memory. BCD-Code (1-2-4-8)		
	"10"	5	6	7	8			
	"100"	9	10	11	12			
	"1000"	13						
Polarity		20				1 BIT. + = "1"		
Range		a	b				2 BIT a and b	
		17	18					
						Range	a	b
						10	1	1
						100	0	1
						1000	1	0
						OVL.	0	0
Measuring mode		ac	dc				2 BIT ac and dc	
		22	21				Measuring mode	ac
						AC/HF	0	1
						DC	1	0
						Ω	1	1
Transfer		19				= 1 T = 50 μ s Appears at the end of the measuring cycle and can be employed for controlling a printer.		
Stop		23				= 0		
Start						= 1 (min. 100 μ s, max 95 ms for a single measurement)		
Circuit zero		24						

Assembly

The digital output unit PM 9221 consists of :

- 1 printed circuit board (U6)
- A wiring assembly
- A 24-pole amphenol connector.

Mounting

- Disconnect the PM 2421 from the mains and pull the chassis out of the cabinet.
- Fit the additional printed circuit board onto digital unit U4 (Fig. 61) and secure the printed circuit board with two M3x5 mm screws.
- Connect the connection cable to the digital printed circuit board by means of the AMP connectors, in accordance with connection diagram Fig. 61.
- Detach the rear panel of the PM 2421 by loosening the 6 screws and pull the plate about 2 to 3 cm backwards.
The connections to the supply unit should remain intact.
- Remove the cover plate for the digital output socket and fit the 24-pole socket block. The cable form is so as to permit the socket being brought in position and secured from the inside of the instrument.
- Refit the rear panel and tie up the cable form at a few spots.
- Slide the instrument chassis back into the cabinet.

Components

TS601...TS622	5322 130 40332	Transistor BC107B
GR601	5322 130 30346	Zenerdiode BZY88/C12
GR602	5322 130 30767	Zenerdiode BZY88/C5V1
GR603	5322 130 30759	Zenerdiode BZY88/C5V6
GR604 } GR605 }	5322 130 40182	Diode BAX13
CS2	5322 267 60008	24-pole amphenol connector

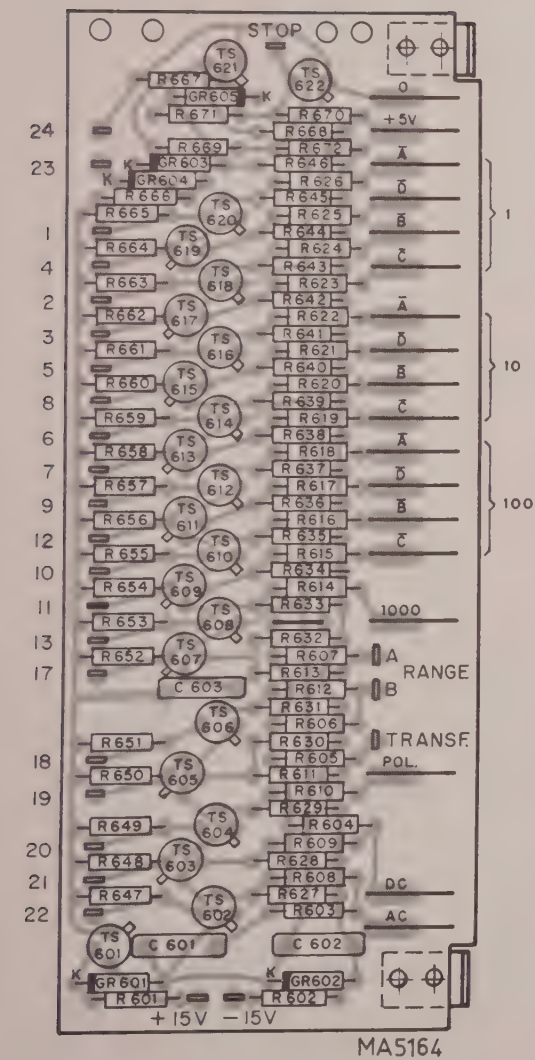


Fig. 62 Printed circuit board PM 9221 (U6)

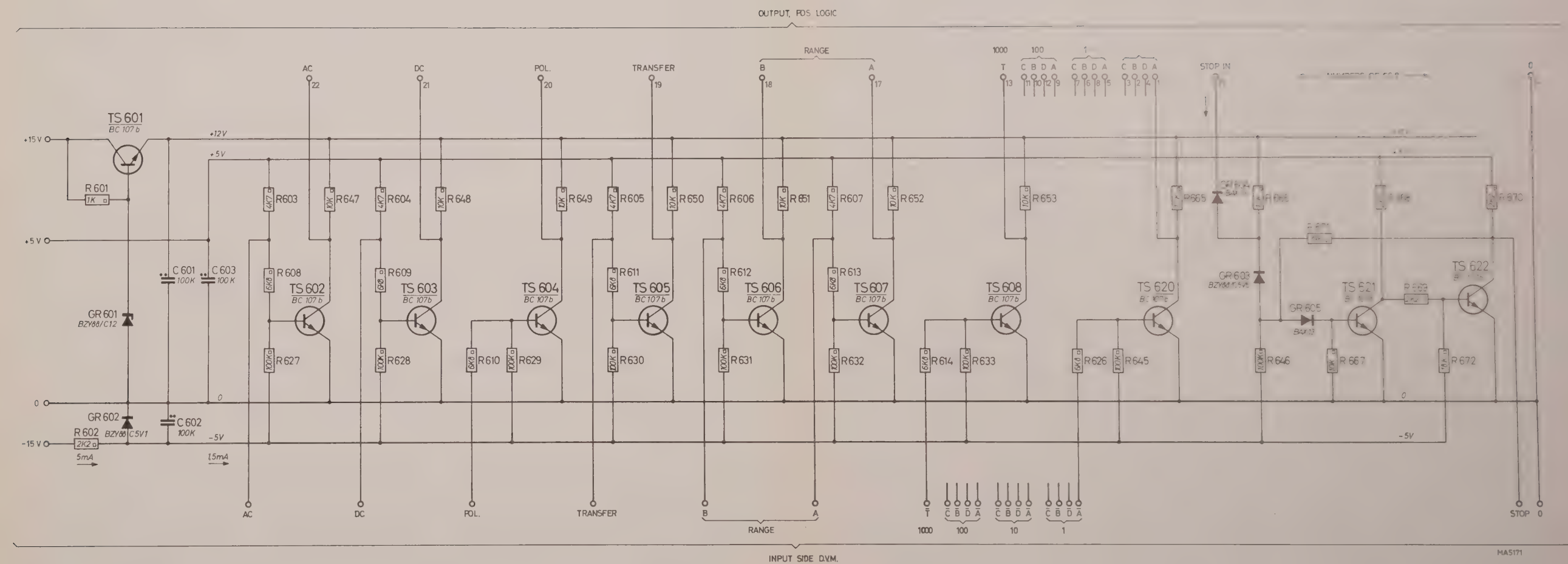


Fig. 63 Circuit diagram PM 9221

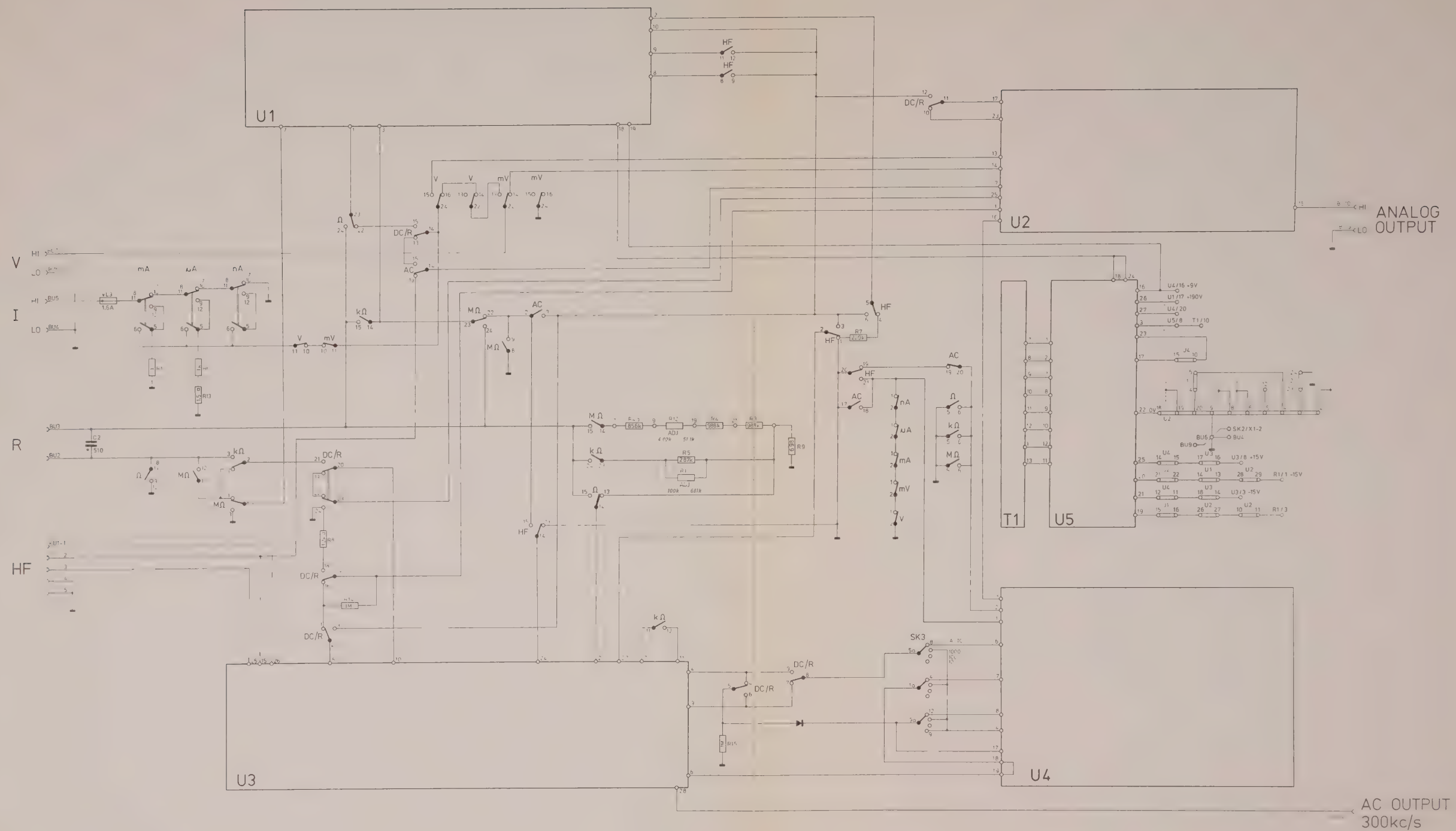


Fig. 64 Wiring diagram PM 2421

QUALITY REPORTING

CODING SYSTEM FOR FAILURE DESCRIPTION

The following information is meant for Philips service workshops only and serves as a guide for exact reporting of service repairs and maintenance routines on the workshop charts.

For full details reference is made to Information G1 (Introduction) and Information Cd 689 (Specific information for Test and Measuring Instruments).

LOCATION

Unit number

e.g. 000A or 0001 (for unit A or 1; **not 00UA or 00U1**)

or: Type number of an accessory (only if delivered with the equipment)

e.g. 9051 or 9532 (for PM 9051 or PM 9532)

or: Unknown/Not applicable
0000

COMPONENT/SEQUENCE NUMBER

Enter the identification as used in the circuit diagram, e.g.:

GR1003	Diode GR1003
TS0023	Transistor TS23
IC0101	Integrated circuit IC101
R0....	Resistor, potentiometer
C0....	Capacitor, variable capacitor
B0....	Tube, valve
LA....	Lamp
VL....	Fuse
SK....	Switch
BU....	Connector, socket, terminal
T0....	Transformer
L0....	Coil
X0....	Crystal
CB....	Circuit block
RE....	Relay
BA....	Battery
TR....	Chopper

CATEGORY

☐

- 0 Unknown, not applicable (fault not present, intermittent or disappeared)
- 1 Software error
- 2 Readjustment
- 3 Electrical repair (wiring, solder joint, etc.)
- 4 Mechanical repair (polishing, filing, remachining, etc.)
- 5 Replacement
- 6 Cleaning and/or lubrication
- 7 Operator error
- 8 Missing items (on pre-sale test)
- 9 Environmental requirements are not met

Parts not identified in the circuit diagram:

990000	Unknown/Not applicable
990001	Cabinet or rack (text plate, emblem, grip, rail, graticule, etc.)
990002	Knob (incl. dial knob, cap, etc.)
990003	Probe (only if attached to instrument)
990004	Leads and associated plugs
990005	Holder (valve, transistor, fuse, board, etc.)
990006	Complete unit (p.w. board, h.t. unit, etc.)
990007	Accessory (only those without type number)
990008	Documentation (manual, supplement, etc.)
990009	Foreign object
990099	Miscellaneous

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